Swansea Valley Business Park, Ystalafera

Flood Consequences Assessment

April 2020

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Client Name: CB3 Consult Ltd.
Document Reference: FCA/01
Project Number: J009

Issue	Date	Author	Comments
01	14.04.2020	Graeme Tulip BEng CEng MICE	First Issue

Contents

Appendices

1. Introduction

1.1 Terms of Reference

Tulip Engineering Consultancy was commissioned by CB3 Consult Ltd to prepare this Flood Consequences Assessment (FCA) to support a planning application for the development of Industrial Units on brownfield land at Swansea Valley Business Park, Glan Yr Afon, Ystalyfera. Industrial development is classified as "less vulnerable" development in Technical Advice Note (TAN) 15 Development & Flood Risk (Welsh Assembly Government, 2004).

The proposed development site lies within Zone C2 of the Development Advice Map (DAM) published by Natural Resources Wales (NRW). Zone C2 is defined as areas at risk of flooding "without significant flood defence infrastructure" (Welsh Assembly Government, 2004).

The objective of this report is to undertake a study into the hydrological issues affecting the site, and establish whether and to what extent the consequences of flooding can be managed over the lifetime of the development, using the principles and tests set out in TAN 15.

2. Site Description

2.1 Location

Swansea Valley Business Park is an established industrial site which lies between Ystalyfera to the north and Godrergraig to the south. The site is directly bounded to the east by the A4067 Glanyrafon Road, with the banks of the River Tawe situated parallel to the road and approximately 70m away in the south-easterly direction.

The National Grid Reference for the site is: SN 76505 08226.

A site location plan is shown in Figure 1.

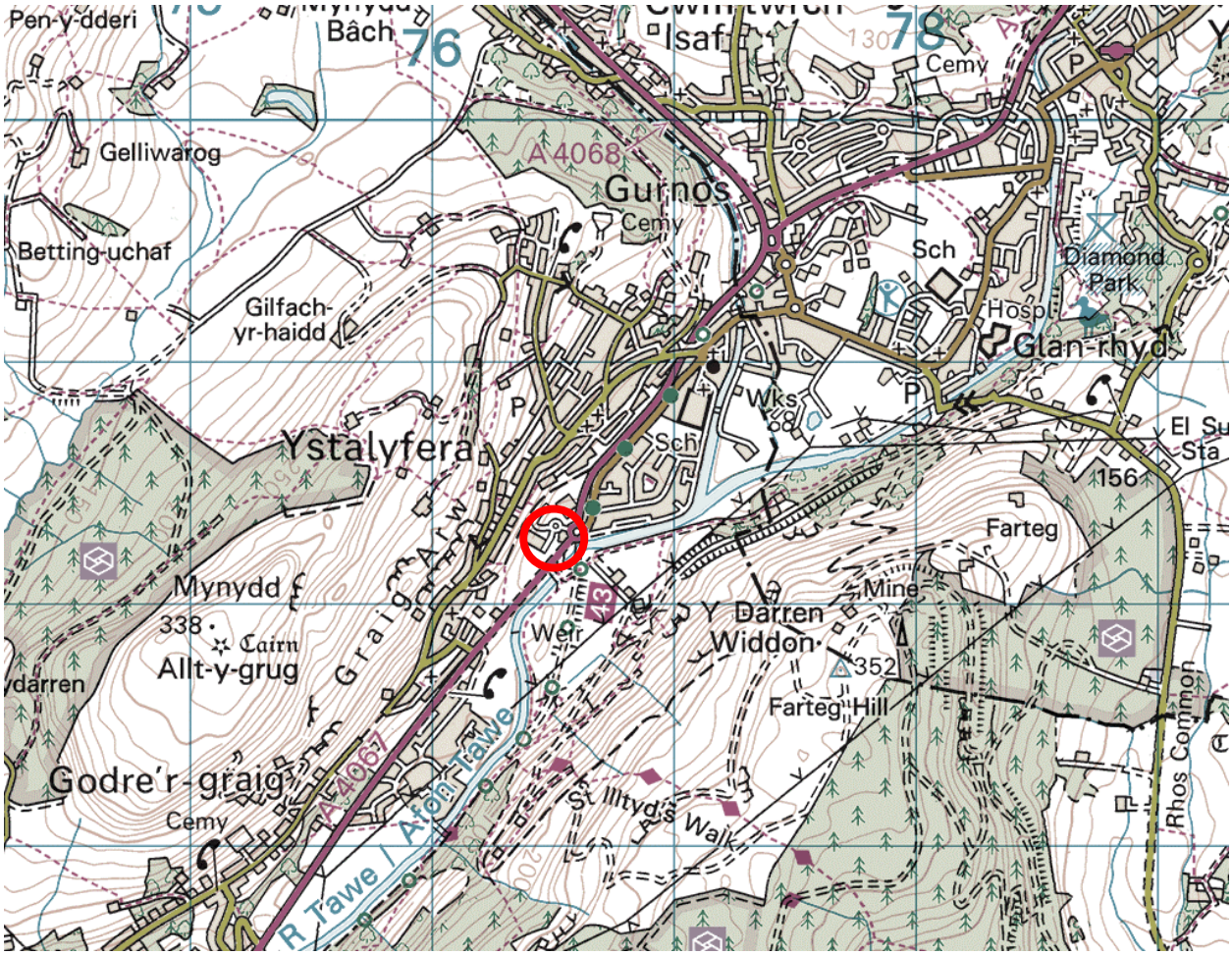


Figure 1: Site Location *Ordnance Survey Data © Crown Copyright and Database Right 2020*

An aerial view of the site is shown in Figure 2.

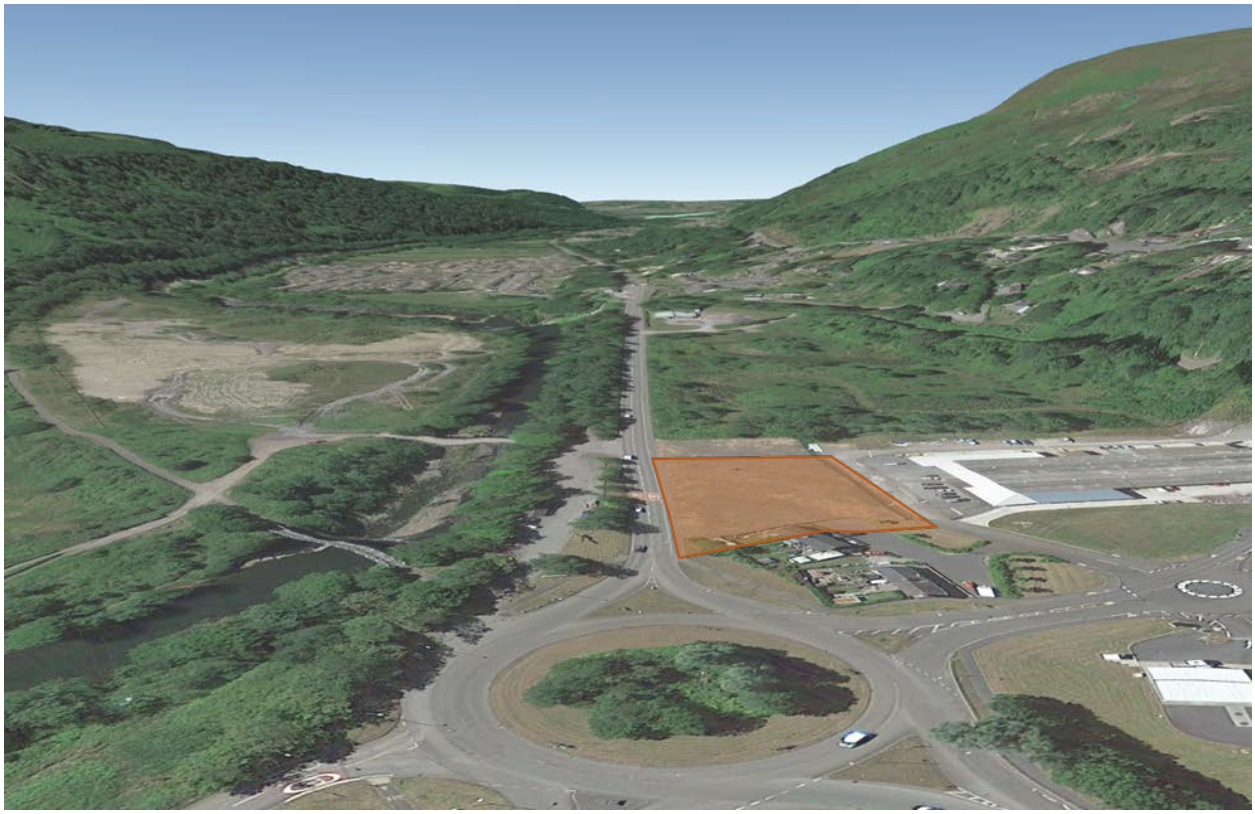


Figure 2: Aerial View showing Site Location *© 2020 Google*

2.2 Watercourses

The Afon Tawe is a designated main river which rises in the Brecon Beacons above Llyn y Fan at 590m above sea level and flows in a generally south-westerly direction to Swansea Bay. The river drains a total catchment of some 270km^2. The Tawe flows approximately 70m to the east of the proposed development.

The Afon Twrch, also a designated main river and a main tributary of the Tawe, rises in the Black Mountains and flows in a generally southerly direction to Ystalyfera where it joins the Tawe approximately 0.7km north-east of the development site. The Afon Twrch catchment is approximately 50km^2 at the confluence with the Tawe.

2.3 Topography

The development site sits in the relatively flat Tawe valley floor some 70m from the river. The width of the valley floor is some 0.8km at this point. The valley floor area widens markedly upstream (north) of the site, where the Twrch joins the Tawe and the two valleys merge.

A plan showing the site location, lidar ground levels, and all OS-mapped watercourses (main rivers and ordinary watercourses) in the vicinity is included in Appendix A.

A topographical survey of the development area and adjacent industrial unit dated March 2016 is also included in Appendix A. This shows that the level of the rectangular development plateau is raised some 1m above the adjacent industrial land to the west.

The development site elevation ranges between approximately 58.0m AOD at the northern end to 59.0m AOD at the southern end. The large existing industrial unit and the industrial estate access road immediately to the west are at a lower level of approximately 56.8m AOD. The main road (A4067) to the east is at a similar level to the development site.

2.4 Soils, Geology & Hydrogeology

Site soils are described as loamy in texture and freely draining according to the Cranfield University Soilscapes Viewer.

The geology at the site is described as superficial alluvial deposits (clay, silt, sand and gravel) overlying mudstone, siltstone and sandstone bedrock, according to the BGS Geology of Britain Viewer.

The aquifer designation of the sedimentary bedrock is Secondary A (capable of supporting water supplies at a local rather than strategic scale). The site is not in a groundwater Source Protection Zone area.

2.5 History

The area in the vicinity of the site was historically the location of the Ystalafera Iron & Tin Plate Works. An overlay showing the site location in relation to the 1910 OS Map is shown in Figure 3.

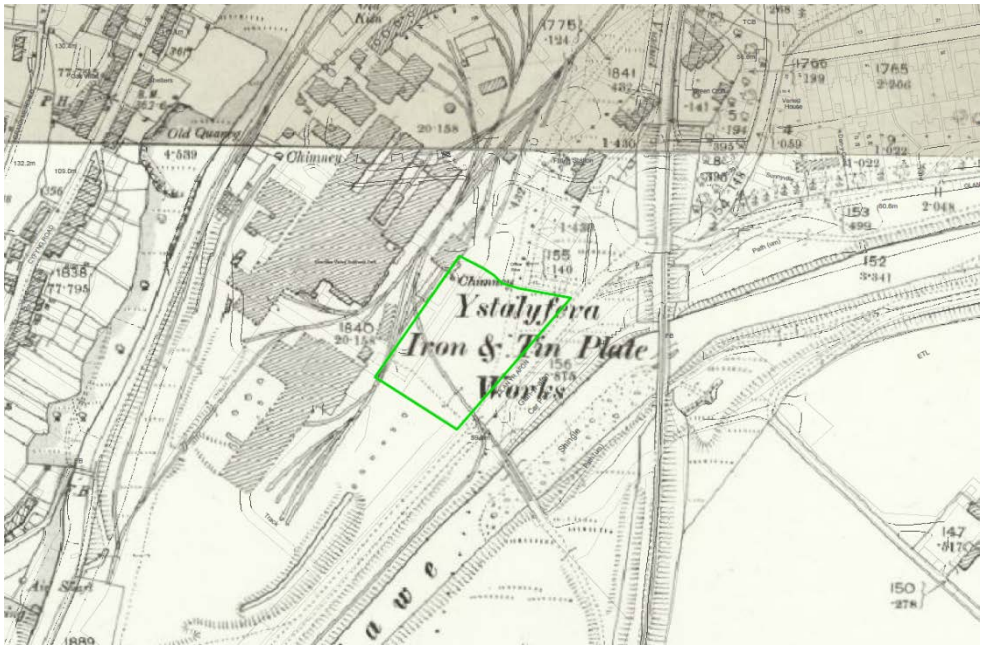


Figure 3: Historical OS Map showing Site Location *Ordnance Survey Data © Crown Copyright 2020*

3. Proposed Development

3.1 Layout

The proposed development consists of two industrial sheds housing seven business starter units, with associated access road and parking spaces.

The existing industrial estate access road is to be realigned to run some 7m closer to the existing adjacent industrial building, to increase the developable area of the plot.

Proposed architectural plans and elevations are included in Appendix B.

3.2 Levels

Proposed carpark and building floor levels are not yet finalised, although it is anticipated that proposed ground levels will be similar to existing levels, with small localised differences due to cut/fill redistribution to flatten out the bank at the northern site boundary.

The realigned access road profile will need to be set to ensure suitable access to both the proposed site and tie in to the adjacent large existing industrial unit.

4. Planning Policy and Flood Risk

4.1 Proposed Development and TAN 15

The development proposal is for industrial units on brownfield land in an industrial area of Ystalafera. Industrial development is classified as 'less vulnerable' development in TAN 15.

The Development Advice Map (DAM) is a flood map published by NRW for land use planning purposes. It is used alongside Planning Policy Wales and Technical Advice Note (TAN) 15 to direct new development in respect to flood risk. Together, they form a precautionary framework to guide planning applications.

The map is based on Natural Resource Wales' extreme flood outlines (zone C) and the British Geological Survey drift data (zone B). Zone B data was originally published 2004 and updated in 2017. Zone C data is revised quarterly by ongoing hydraulic modelling and represents areas affected by flooding in events with up to a 1 in 1000 annual chance of occurring (0.1% Annual Event Probability), but no allowance for future climate change.

The Development Advice Map in the vicinity of the proposed development is included in Appendix C. The Map shows that the development site currently lies within the blue shaded zone C2 area, defined as "*areas of the floodplain without significant flood defence infrastructure*".

TAN15 provides for less vulnerable development in zone C2, subject to application of the justification test, including acceptability of consequences.

4.2 Justification Test

TAN15 Section 6 states that development will be justified if it can be demonstrated that:

1. Its location in zone C is necessary to assist or be part of a local authority regeneration initiative or a local authority strategy required to sustain an existing settlement; **or**

2. Its location in zone C is necessary to contribute to key employment objectives supported by the local authority, and other key partners, to sustain an existing settlement or region; **and**

3. It concurs with the aims of Planning Policy Wales and meets the definition of previously developed land; **and**

4. The potential consequences of a flooding event for the particular type of development have been considered and found to be acceptable.

In this case this development is considered to meet the second and third criteria, whilst the fourth is supported by updated flood modelling undertaken specifically for this FCA, as described in Section 6 and Appendix D of this report.

5. Existing Flood Risk Review

5.1 Historical Flooding

The site has not experienced any flooding in the past according to NRW's map of historical flood outlines.

5.2 Fluvial Flood Risk

The NRW Zone 2 & 3 Map in Appendix C shows the lower part of the site in zone 3 (up to 1 in 100 annual chance of flooding) and the remaining higher part of the site in zone 2 (up to 1 in 1000 annual chance of flooding).

This map also indicates that the zone 3 area is classed as 'area benefitting from flood defences', although this area is not shown as green-coloured zone C1 (defended) on the DAM Map.

A additional 'Flood Zone Plan' is included in Appendix C, showing flood zones 2 & 3 overlaid on an map which also includes the site topographical survey, lidar ground elevation data and OS watercourses.

It is important to note that this is the fluvial flood risk as shown on the current (existing) flood maps which guide the planning process. The updated fluvial flood modelling described in Section 6 effectively supersedes this existing fluvial flood risk.

5.3 Surface Water Flood Risk

The surface water flood risk map included in Appendix C shows a high risk area along the existing access road to the industrial estate, with the remainder of the development plot in very low or low risk area.

The existing access road will be reprofiled and drained as part of this development proposal. Furthermore the development site itself will be subject to sustainable drainage design/SAB approval and as such it is considered unlikely that the proposed development will increase the risk of surface water flooding or the rate and volume of surface water runoff.

5.4 Reservoir Flood Risk

The development site is not at risk of flooding from reservoir failure according to NRW's flood risk mapping.

5.5 Groundwater Flood Risk

The development site is not in an area prone to groundwater flooding according to available BGS mapping, which is supported by NPT's Local Flood Risk Management Strategy which states that there are no specific areas of groundwater flooding recorded historically in the NPT area.

6. Hydraulic Modelling

6.1 Existing Hydraulic Model

This section of the report will reassess the flood risk indicated by the DAM maps and establish whether the consequences of the risk of flooding may be considered acceptable.

The current DAM Map flood outline in the site locality is informed by the results of flood modelling undertaken in 2016 by JBA Consulting for the Ysgol Gyfun Ystalafera Flood Consequences Assessment. This model was in turn based largely on a 2013 Cwm Twrch 1D-2D model also developed by JBA Consulting on behalf of NRW.

The hydrology calculations from 2016 have now become outdated due to ongoing developments in hydrology methods, guidance and data availability. As part of this development FCA, updated hydrology and modelling has been commissioned.

6.2 Updated Hydraulic Modelling

The updated modelling undertaken by JBA Consulting for this FCA encompassed updated hydrology (input flow) calculations, more realistic application of input flows and 1D model updates. Model scenarios were run using the latest TUFLOW software and current climate change (30%) allowance.

A Technical Note from JBA Consulting summarising the updated modelling exercise, is included in Appendix D of this report.

Results from the updated modelling show that the proposed development floods in **neither** the 1 in 100 (1%) AEP with climate change allowance, **nor** the 1 in 1000 (0.1%) AEP. The 0.1% AEP flood map extent is shown in Figure 4.

Flooding is shown to emanate from the right bank of the Afon Twrch some 1km upstream of the site at Ysgol Gyfun Ystalafera. The overland flood flow-path is then southerly before ponding around Varteg Road, but does not reach beyond the roundabout towards the development site.

TAN15 guidelines require a flood-free development level for fluvial flood risk of 1% (1 in 100 annual chance) probability over the lifetime of the development. The updated modelling results displayed in Figure 4 show that the proposed development would be compliant with the flood-free development level criteria (A1.14) of TAN15. Consequently it is clear that no ground level alterations would be required in order to meet this criteria.

Emergency access/egress to/from the site needs to be considered in light of the TAN15 recommendations. The map in Figure 4 indicates that the immediate site access road and mini-roundabout would be flood free during the 0.1% AEP event. The main A4067 Glan Yr Afon road roundabout is shown to suffer flooding up to a depth of 0.6m on the eastern side, which is within the "maximum permissible floodwater depth over the defined route during extreme flooding" figure of 1.0m given in A1.15 of TAN15.

Whilst access to the A4067 during the 0.1% APE event may be hampered, the availability of the B4599 would be unaffected and would allow for safe evacuation from the site or access for emergency vehicles if required.

The 'no flooding elsewhere' criterion of TAN15 is considered negligible in this assessment since it has been demonstrated that the site would not flood during either the 1%CC or 0.1% AEP events.

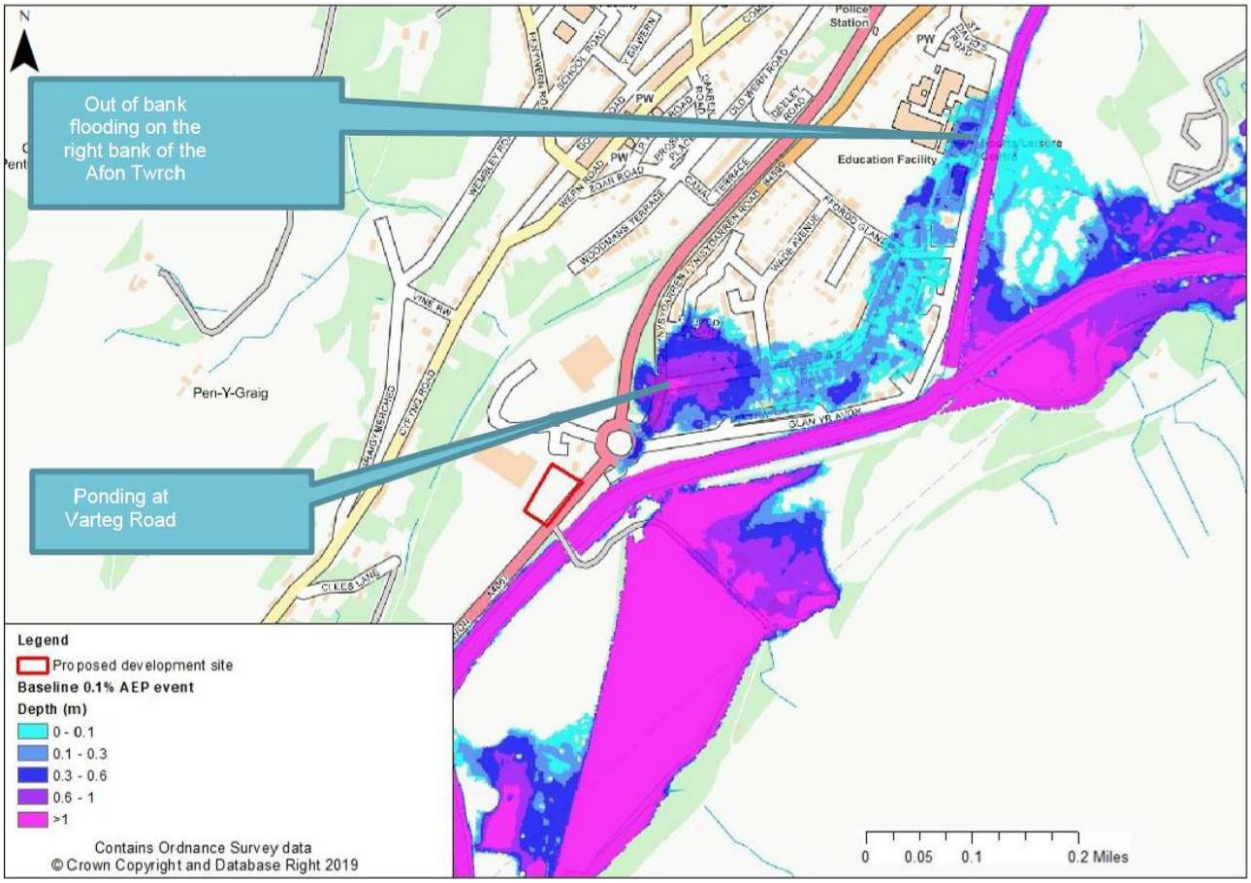


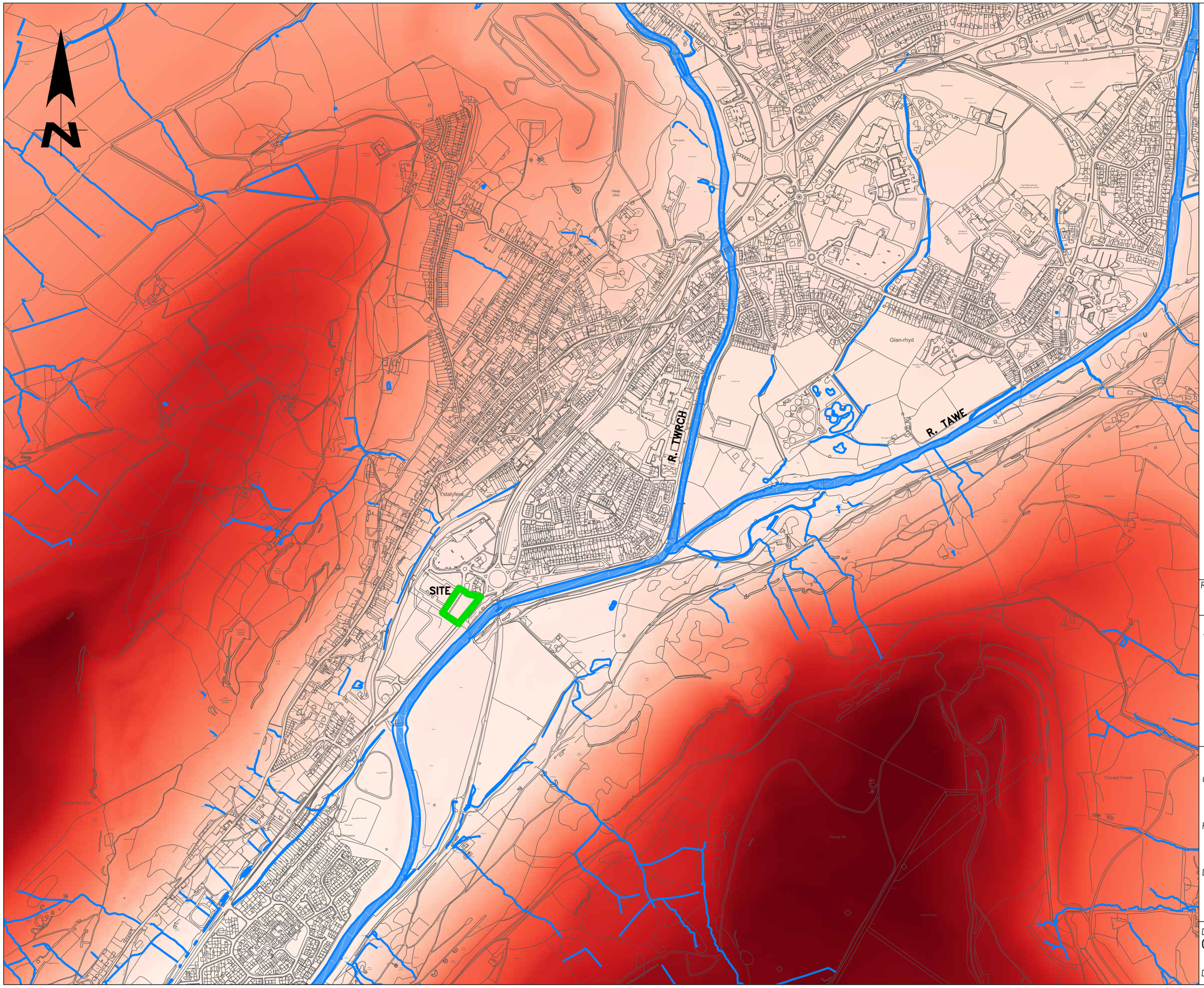
Figure 4: Updated Model: 0.1% AEP Flood Depths

7. Conclusions & Recommendations

- This planning application is for industrial development (classed as less vulnerable in TAN15) on brownfield land at Swansea Valley Business Park.
- The requirement for this FCA is due to the proposed development site location in the flood plain (zone C2 of the current Welsh Government Development Advice Map).
- However, updated flood modelling undertaken specifically for this FCA for this development, has demonstrated that the proposed development site is outside the flood plain, that is, flood-free during both the 1%CC and 0.1% AEP events.
- The most up to date analysis of flood risk to the site is therefore shown to be less than that suggested by the current DAM Map, and the key TAN15 acceptability tests in relation to flood-free floor level, no flooding elsewhere and access/egress are all met by default.
- The proposed development is compliant with all key aspects of TAN15 and as such it is considered that this land is suitable for industrial development in relation to planning policy and flood risk.

APPENDICES

A. LIDAR Plan, Topographical Survey Plan



Lidar Ground Elevation

- 40 mAOD
- 100
- 160
- 220
- 280
- 340

OS-MAPPED WATERCOURSE

REV | DATE

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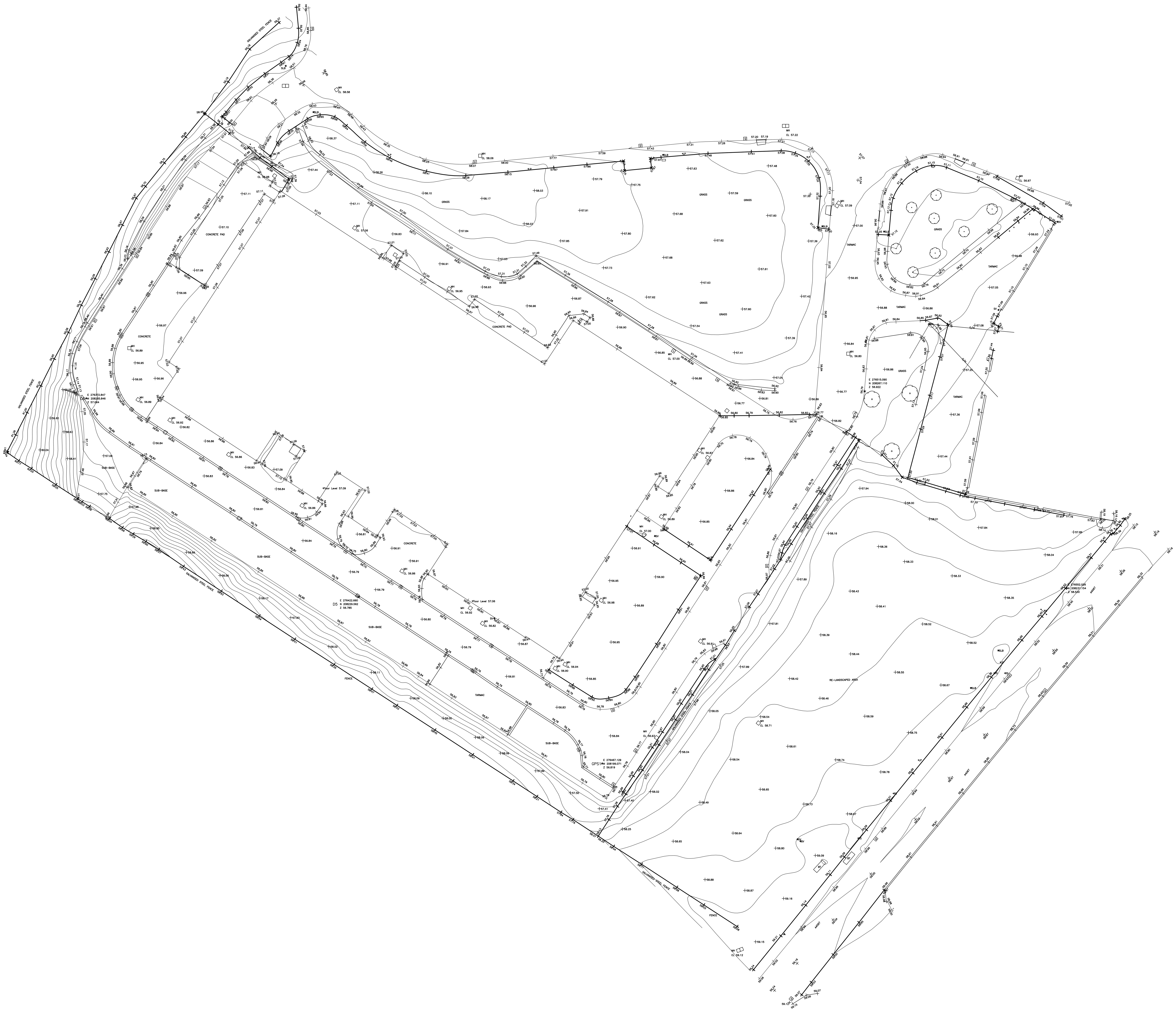
CLIENT: CB3 CONSULT LTD

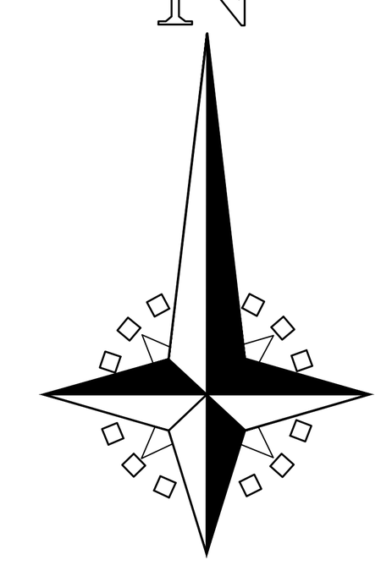
PROJECT: SWANSEA VALLEY IND. EST. FCA

DRG TITLE: **LIDAR PLAN**

DATE:	STATUS:	SCALE:
09.04.2020	PLANNING	1:10,000

DRG NO. **J009/001** REV. - SIZE: A3





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Contract

Mr Paul James
Swansea Valley Business Park
Glanyrafon Roundabout
Ystalyfera
SA9 2EE
Topographical Survey

Drawing Number	10007/001/CD/DLO
Scale	**1/250 @ A0**
Date	24/03/2016
Drawn by	DLO

B. Architectural Site Plan, 3D Image

SCALE
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Rev.	Desc.	Date
1	Pre app final	25–03–20

Total Carparking – 48 Spaces

Areas :

GF Units 1–4 : 245m2
FF Units 1–4 : 245m2

Totals :
GF – 981m 2
FF – 981m 2
GF+FF – 1962m 2

Areas :

GF Units 5–7 : 118m 2
FF Units 5–7 : 118m2

Totals :
GF – 356m 2
FF – 356m 2
GF+FF – 712m 2

981m 2 + 490m2 +356m2 + 2 = 2 /120 =
parking spaces for worksh 238m 2065m 17

490m 2 + 119m2 = 609m2 /20 = 31 parking spaces
offices for

Full Planning Layout

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Falcon Chambers
Thomas St. Llanelli
SA15 3JB
www.wgriffiths.co.uk
Tel. 01792 651532

PROJECT
Ystalyfera Commercial

SCALE 1 : 500
SIZE A3
DRAWN
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DATE 10/29/19
DATE

TITLE
Full Planning Layout

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Rev.	Desc.	Date
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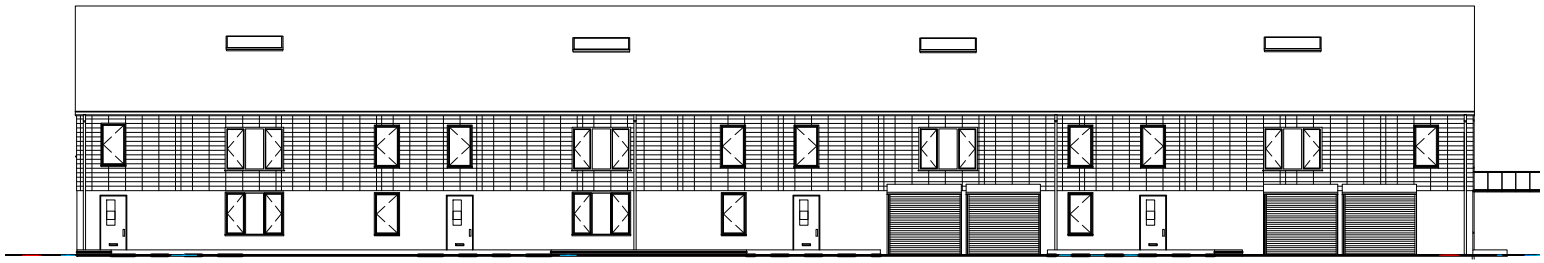

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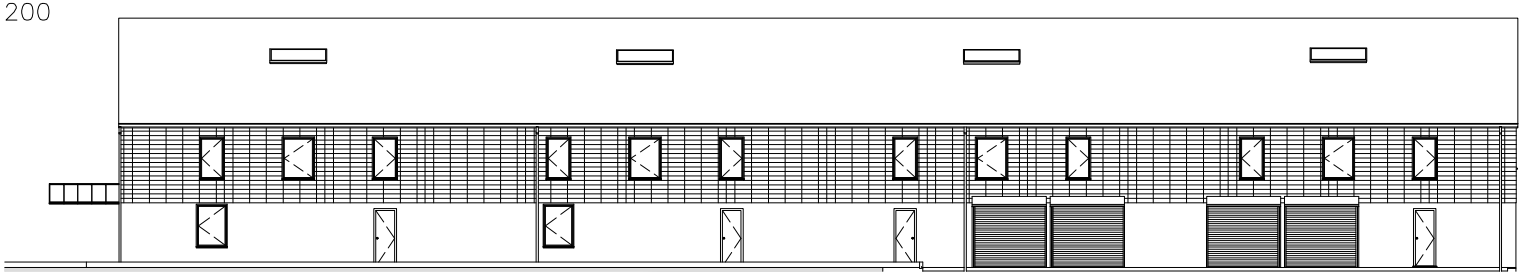

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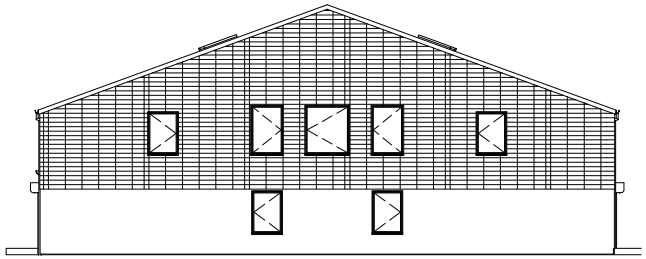

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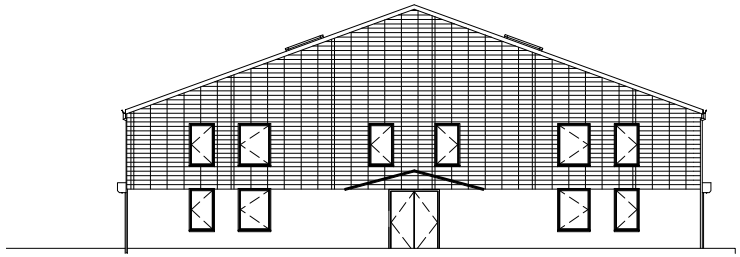

4 Elevation 4 – Block
A1 :
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Proposed Elevations – Block A

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PROJECT
Ystalyfera Commercial

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DRAWN		DATE	02/09/19
CHECKED	Checker	DATE	

TITLE
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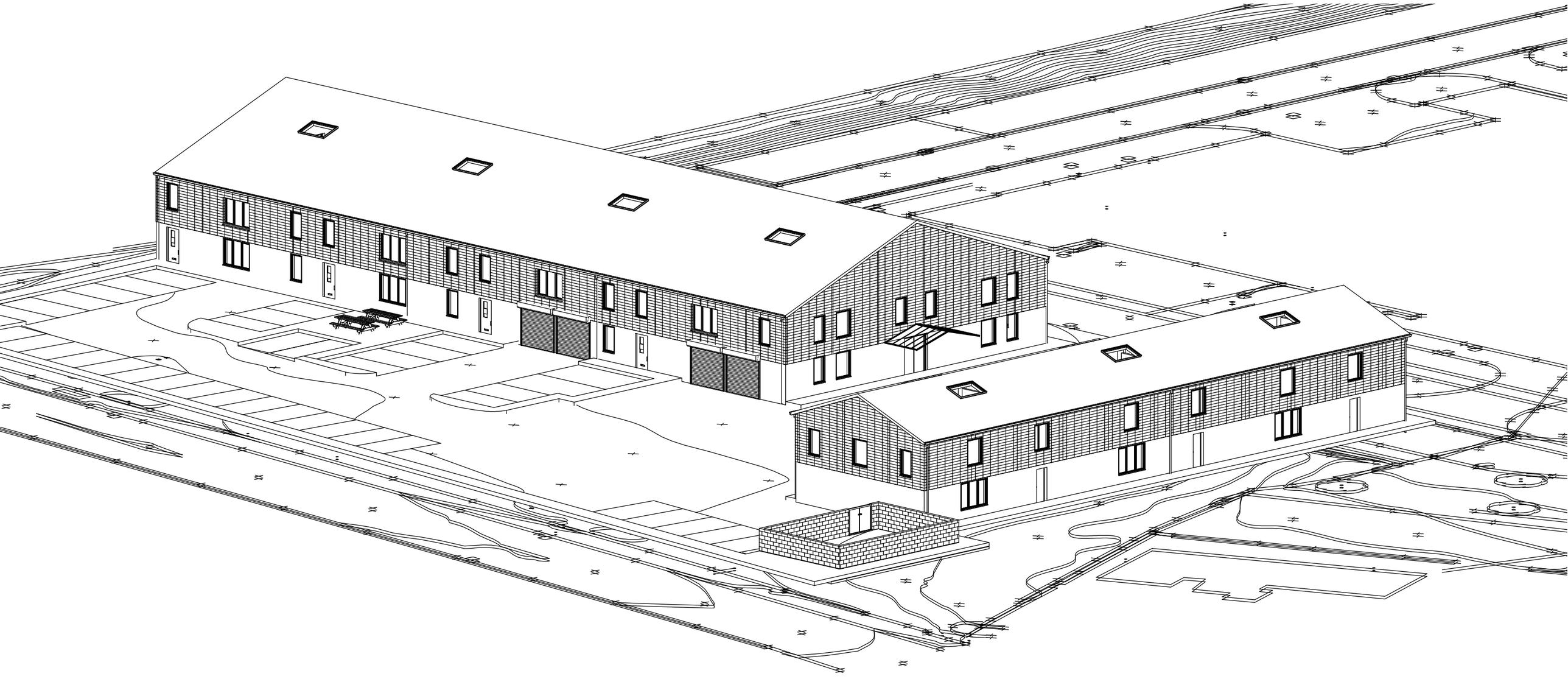

3D View

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PROJECT
Ystalyfera Commercial

SCALE nts
SIZE A3
DRAWN
DATE 02/09/19
CHECKED Checker
DATE

TITLE
3D View

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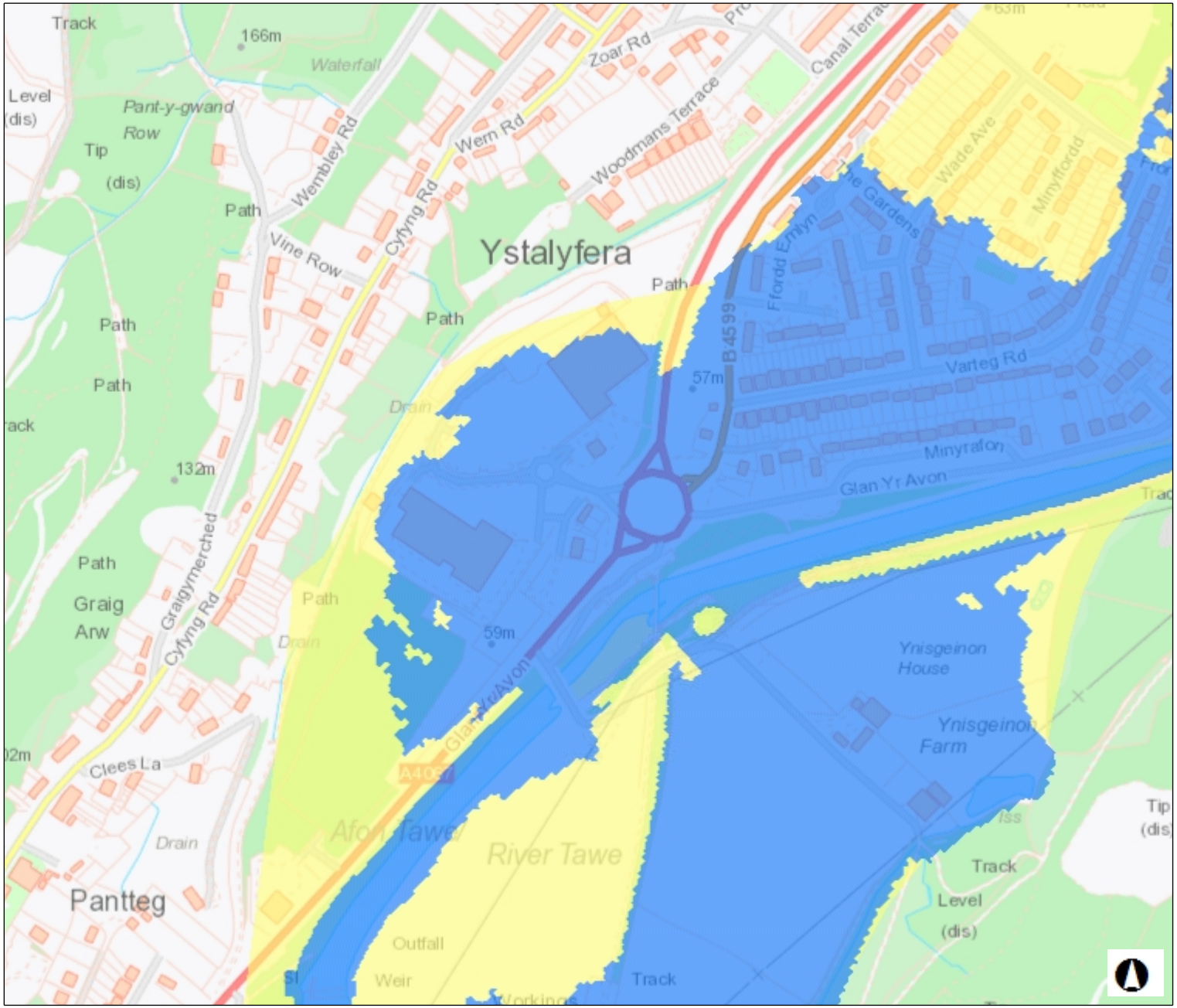
C. Flood Maps



Cyfoeth Naturiol Cymru
Natural Resources Wales

Map Title

Map Perygl Llifogydd / Flood Risk Map

Allwedd / Map Key

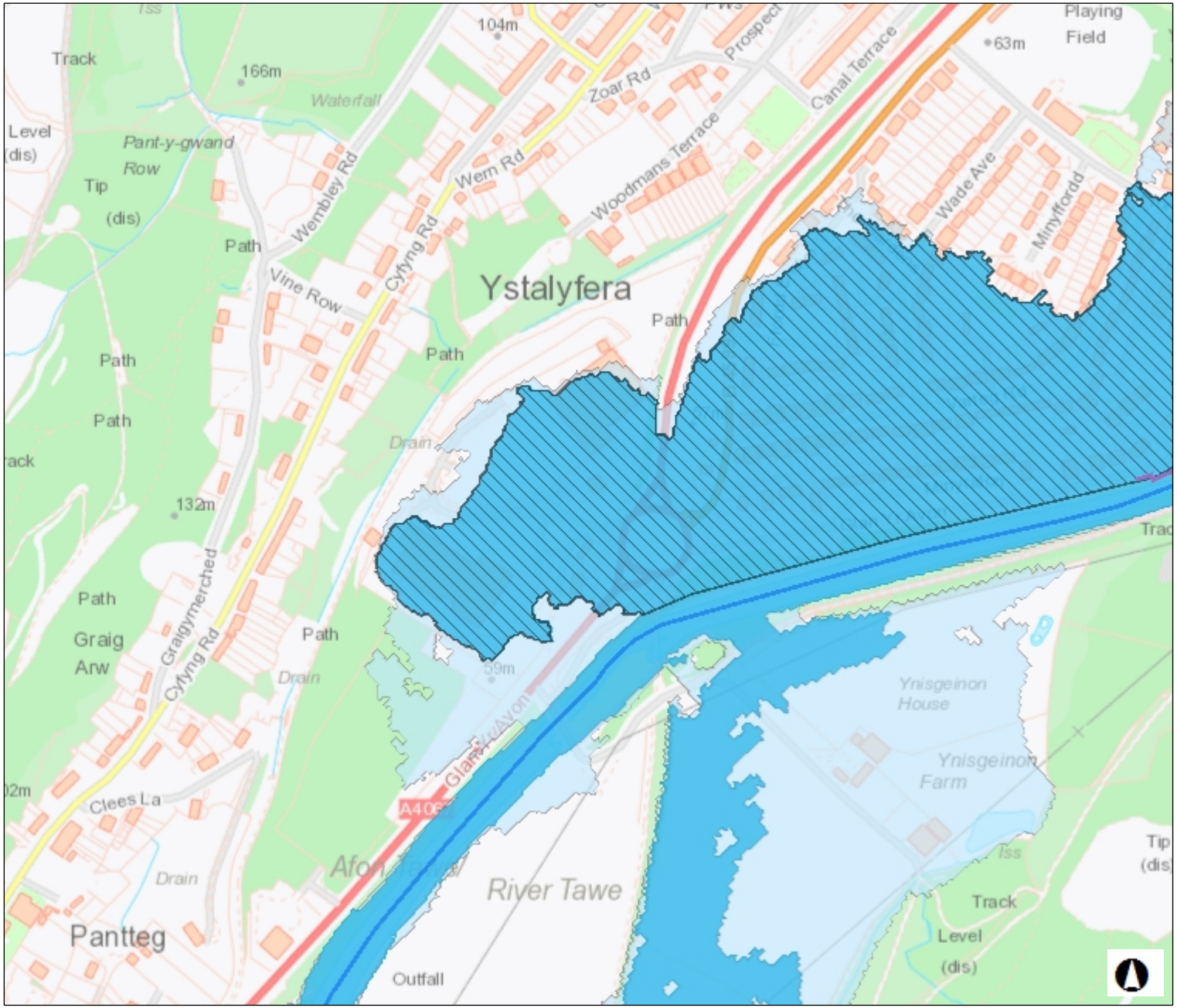
- Zone C1
- Zone C2
- Zone B
- Zone A

Graddfa / Scale 1: 5,001

Dyddiad / Date
12/04/2020

0.3 0 0.13 0.3

British_National_Grid Kilometers



Cyfoeth Naturiol Cymru
Natural Resources Wales

Map Title

Map Perygl Llifogydd / Flood Risk Map

Allwedd / Map Key

- Main Rivers
- Flood Defences
- Areas Benefiting from Flood Defences
- Flood Storage Areas
- Floodmap Flood Zone 3
- Floodmap Flood Zone 2

Graddfa / Scale 1: 5,001

Dyddiad / Date
12/04/2020

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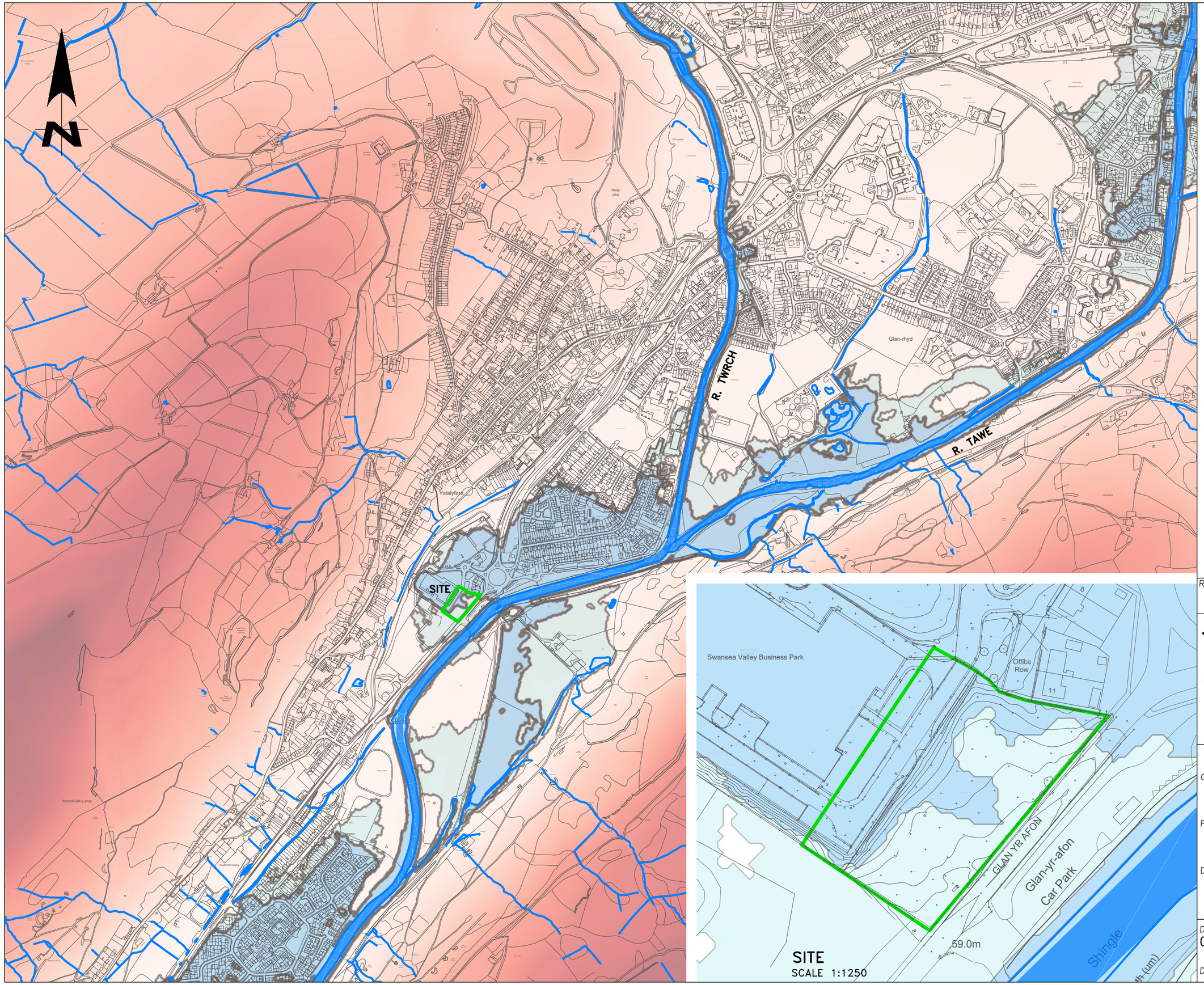
British_National_Grid Kilometers



SITE
SCALE 1:1250

40 mAOD
100
160
220
280
340

OS–MAPPED WATERCOURSE

FLOOD ZONE 3:
UP TO 1% AEP (100yr)

FLOOD ZONE 2:
UP TO 0.1% AEP (1000yr)

REV | DATE

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CLIENT: CB3 CONSULT LTD

PROJECT: SWANSEA VALLEY IND. EST. FCA

DRG TITLE: **FLOOD ZONE PLAN**

DATE: 09.04.2020 | STATUS: PLANNING | SCALE: 1:10,000

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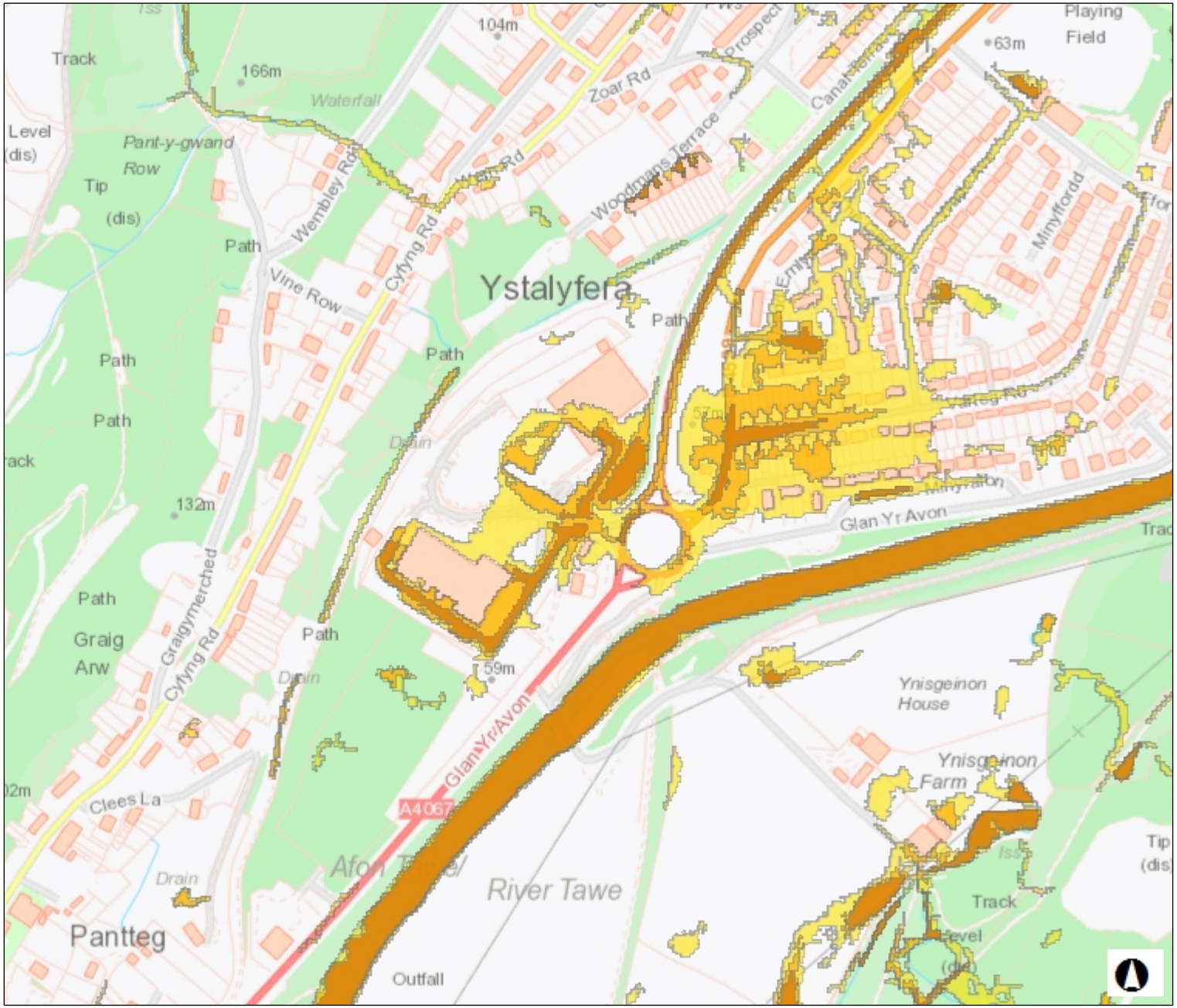


Cyfoeth Naturiol Cymru
Natural Resources Wales

Map Title

Map Perygl Llifogydd / Flood Risk Map

Allwedd / Map Key

- High Surface Water Flood Risk - Extent
- Medium Surface Water Flood Risk - Extent
- Low Surface Water Flood Risk - Extent

Graddfa / Scale 1: 5,001

Dyddiad / Date
12/04/2020

0.3 0 0.13 0.3

British_National_Grid Kilometers

D. Hydraulic Modelling Technical Note

TECHNICAL NOTE

JBA Project Code	2019s0932
Contract	Swansea Valley Modelling
Client	CB3 Consult Ltd
Day, Date and Time	4th September 2019
Author	Adam Sinclair
Reviewer	Amy Evans
Subject	Hydraulic modelling report

1 Introduction

1.1 Terms of reference

JBA Consulting have been commissioned by P & C James to undertake hydraulic modelling of the Afon Twrch and Afon Tawe to support a proposed new development at Swansea Valley Business Park in Glanyafon, Ystalyfera in West Wales. The hydraulic modelling required the updating the existing modelling in the study area as well as updating the hydrological estimates applied to this model.

1.2 Study area

The proposed development site is located on Glan Yr Avon road in Glanyafon. The Afon Tawe flows approximately 50m to the south-east of the proposed development from north to south. The Afon Twrch is located approximately 685m to the north-east of the proposed development. The Ordnance Survey (OS) National Grid Reference for the site is SN 76966 09006.

1.3 Proposed development and planning policy

The proposed development is for industrial units on brownfield land. Industrial development is classified in Technical Advice Note (TAN) 15 as 'less vulnerable' development (Welsh Assembly Government, 2004).

The proposed development site is currently within Natural Resources Wales (NRW)Development Advice Map (DAM) Zone C2, defined as areas at risk of flooding 'without significant flood defence infrastructure' (Welsh Assembly Government, 2004).

The NRW Flood Map is informed by the results of the 2016 Ysgol Gyfun Ystalyfera Flood Consequence Assessment (FCA) 1D-2D model. This model was developed by JBA Consulting as part of an FCA for a school building at the Ysgol Gyfun Ystalyfera Primary School. The 2016 model is largely based on a 2013 Cwm Twrch 1D-2D Flood Hazard Modelling model, also developed by JBA Consulting on behalf of Natural Resources Wales (NRW). The main changes undertaken in 2016, were to include the latest LIDAR, update the representation of the footbridge between Glan Yr Avon and Glanwrch as well as to update the hydrological inflow for the Afon Twrch.

NRW's DAM showing of the proposed development location is shown in Figure 1-1.

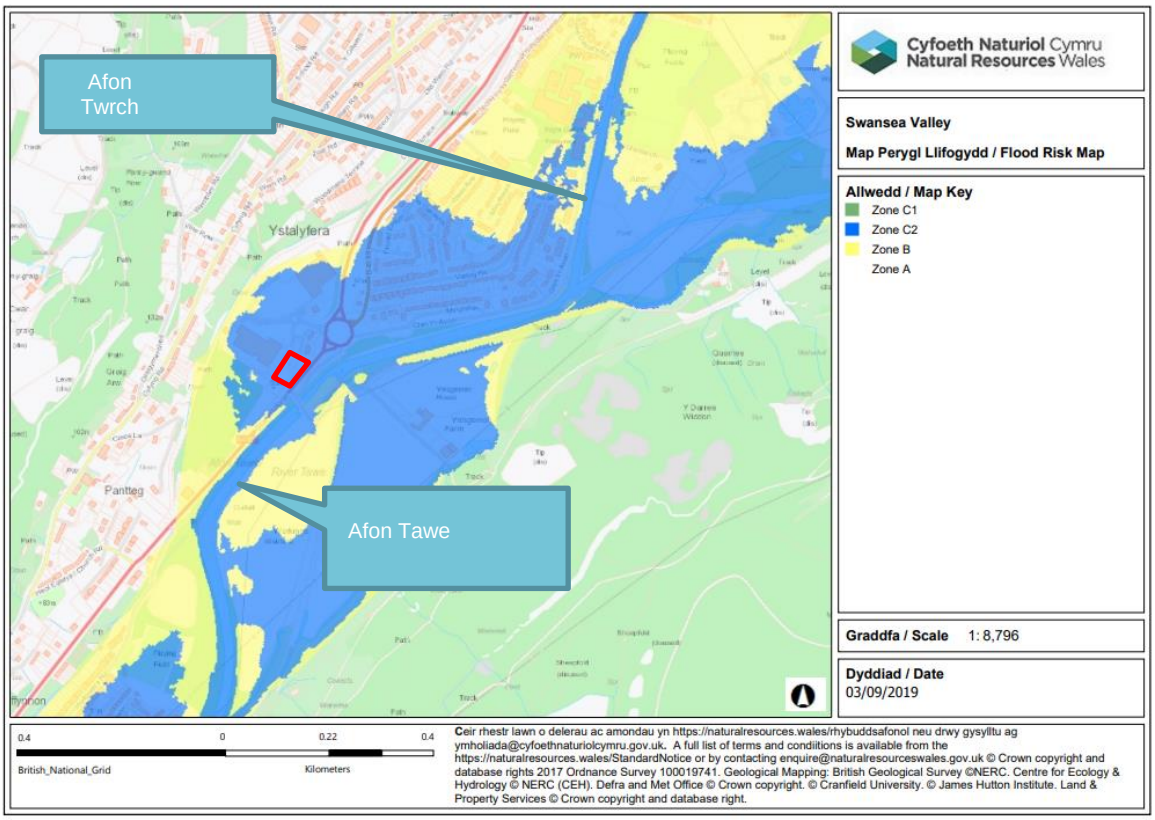


Figure 1-1: NRW's DAM showing the proposed development site location (proposed development site in red)

2 Flood risk assessment

2.1 Hydraulic model

The 2016 Ysgol Gyfun Ystalyfera Flood Consequence Assessment 1D-2D model was updated to assess the flood risk at the Swansea Valley Business Park site.

2.2 Hydrology

The hydrology calculated in 2016 is now outdated due to developments in hydrology methods, guidance and data availability. Therefore, new hydrological inflows were generated for both the Afon Tawe and Afon Twrch. The updated flows have been developed using the Flood Estimation Handbook (FEH) Statistical method as QMED was has been improved by using local donors. Full details of the method used to generate the peak flows can be found in the flood estimation report, in Appendix A. Peak flows derived for this study are provided in Table **2-1**.

Table 2-1: Estimated peak flows

Site code	Flood peak (m^3/s) for the following AEP (%) events		
	50	**1**	**0.1**
TWR_01	66	157	248.8
TAW_01	169	369	576.8
TAW_02	115	252	393.3

The updated hydrology was incorporated within the model as shown in Figure **2-1**. Within the 2016 modelling, the intervening area hydrograph between Taw_01 and Taw_02 was applied as two point inflows. This method has been updated so that the inflow is spread equally across all model nodes on the Afon Tawe. This method has been selected as an inspection of aerial imagery, mapping and LIDAR data shows that there are a large number of small drains on the left bank of the Afon Tawe that drain into the channel throughout the reach represented in the model.

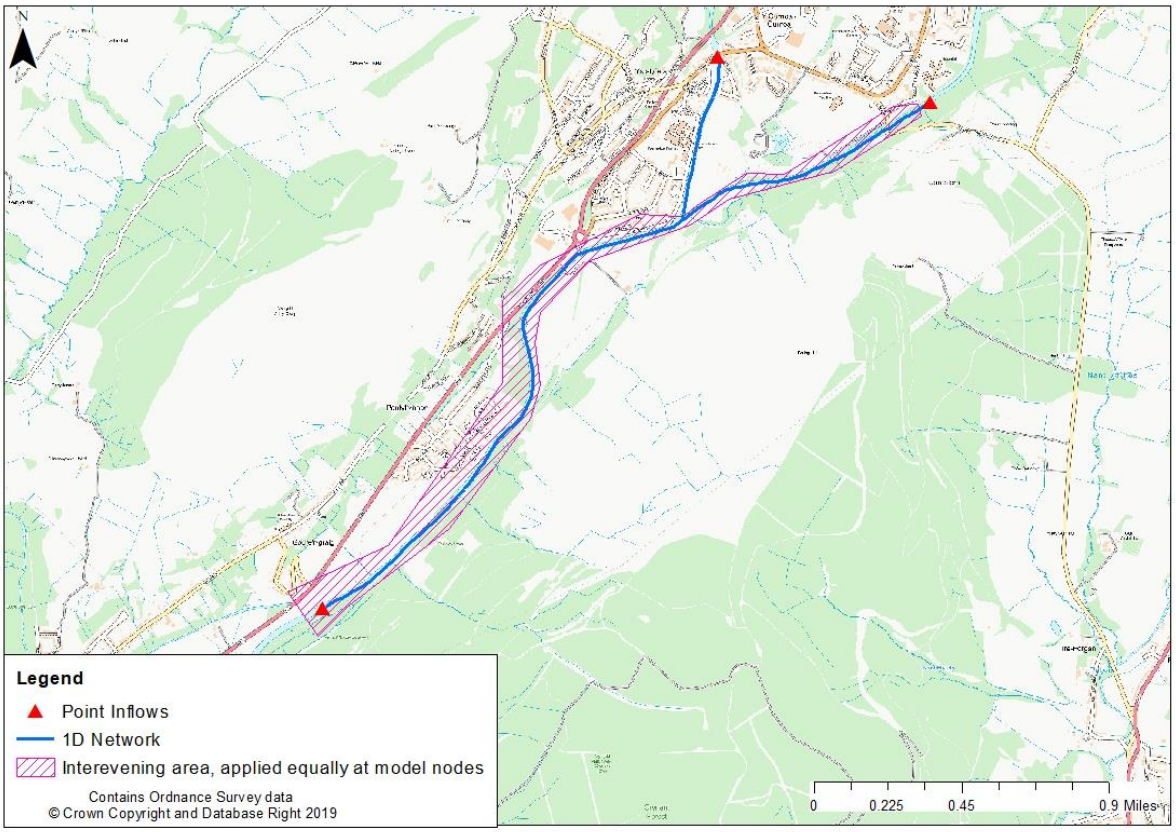


Figure 2-1: Inflows applied to updated model

2.3 1D model updates

The following updates have been made to the 2016 model to ensure that it is in line with current modelling best practice:

- All bridge 'B' channel types have been changed to the newer 'BB' channel type, which automatically calculates losses. Form Loss Values for these structures have been updated to 0.001, unless piers are present at the structures.
- All weir 'W' channel types have been changed to the newer 'WW' channel type. Each structure has been reviewed and an appropriate Cd value selected.

2.4 TUFLOW version

The updated model was simulated with the new hydrology using TUFLOW version 2018-03-AE-iSP-w64.

2.5 Model Scenarios

Simulations were completed for the 1% Annual Exceedance Probability (AEP) event with an allowance for climate change (plus 30% (Welsh Government, 2016) and 0.1% AEP event. The modelling files are shown in Table **2**-**2**.

Table 2-2 Hydraulic modelling files

Run Reference	**TWRC_077_Q0100CC_8.5hr TWRC_077_Q1000_8.5hr**	
Purpose of Runs:	The purpose of this model scenario was to understand the baseline flood risk to the proposed development.	
ISIS/TUFLOW file and Version:	File names:	
	TWRC_077_~e1~_8.5hr.tcf	TAWE_007.tbc TWRC_003_A.tbc
	TWRC_077.ecf	Materials_NWPT.tmf
	bc_dbase_CWMTWRCH_076.csv	CWMTWRCH_076.trd
	TAWE_076.tgc TWRC_008.tgc	
Model Timesteps:	1D model timestep: 1s 2D model timestep: 2s	
Run Time:	Model run time: 20 hours Maximum simulation time: 1:01 hours	
Return period(s):	1% AEP with an allowance for climate change (+30%). 0.1% AEP.	
Run Settings:	Multi-domain model. Defended model.	
Comments on results:	Negative depth warnings: 0 Maximum cumulative ME: 0.50%	

3 Modelling Results

3.1 Mapped Results

3.1.1 Updated 1% AEP plus Climate Change (30%)

Results from the updated modelling show that the proposed development site does not flood during the 1% AEP plus climate change event. The maximum depths for this modelled event are shown in Figure 3-1.

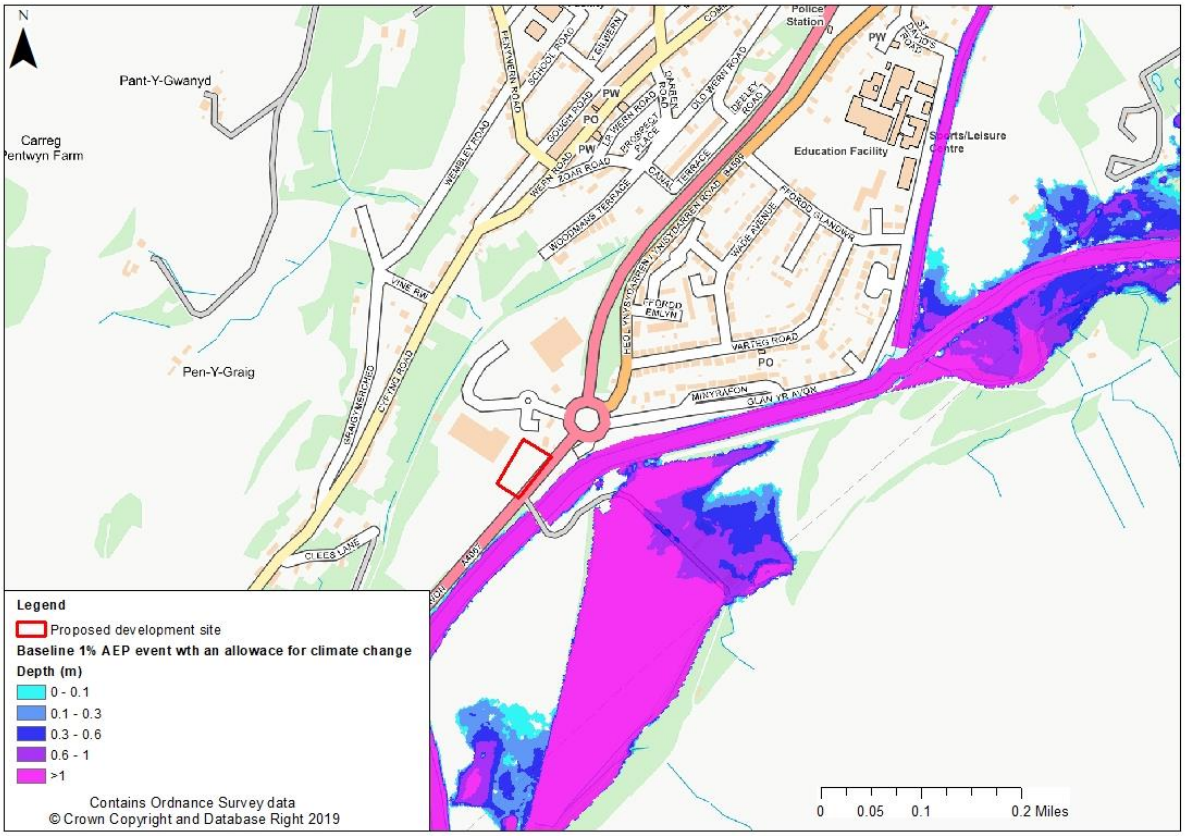


Figure 3-1: 1% AEP plus climate change maximum flood depth

3.1.2 Baseline 0.1% AEP event

Results from the updated modelling show that proposed development site does not flood during the 0.1% AEWP event. Out of bank flooding occurs on the right bank of the Afon Twrch at Ysgol Gyfun Ystalyfera, which flows south before ponding around Varteg Road, approximately 160m to the east of the proposed development. The maximum depths for this modelled event are shown in Figure **3**-**2**.

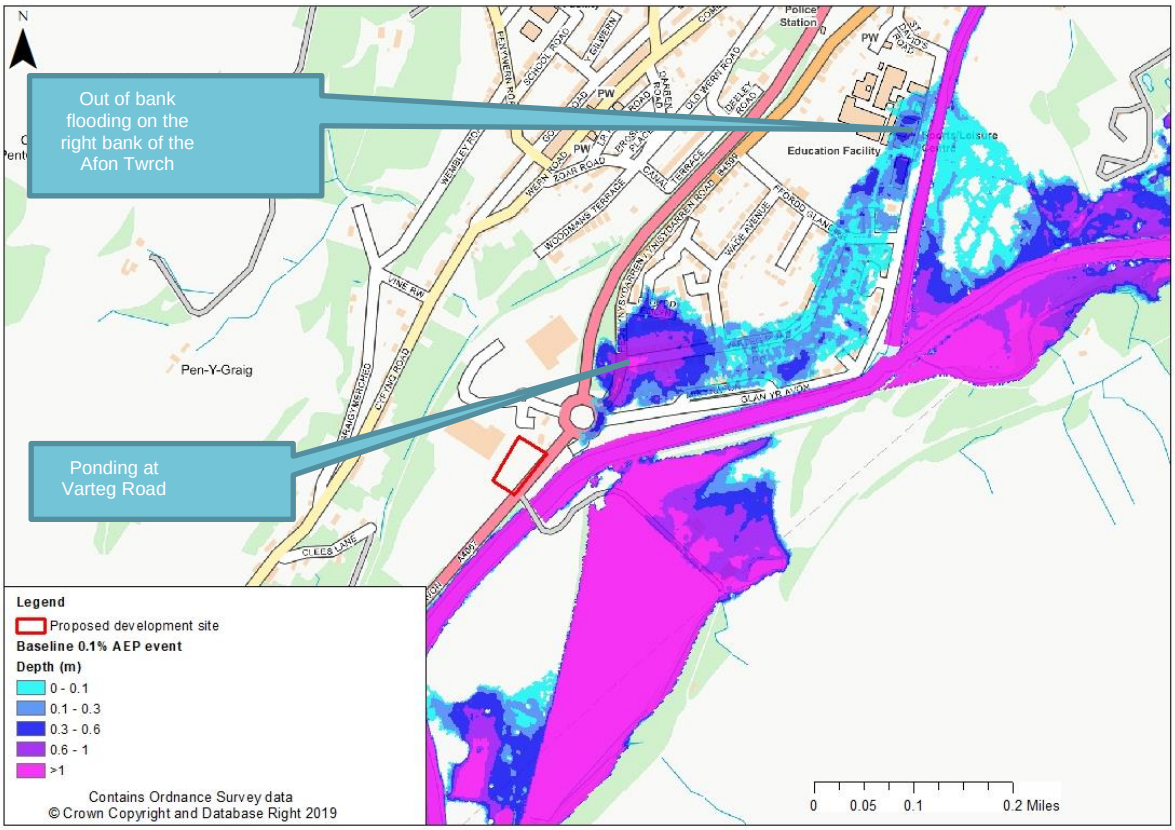


Figure 3-2: Baseline 0.1% AEP event maximum flood depth

3.2 Model performance

- The model ran stably for all events. The model simulation time was approximately 1 hour.
- Peak mass error was 0.50% which occurred during the 0.1% AEP event. This is within the acceptable limit of +/-1%.
- No negative depths occurred in either the 1D or 2D domain for any of the model simulations undertaken as part of this study.
- A total of 36 check and warning messages were generated during the simulation. None of them are messages that didn't occur during the original modelling.

3.3 Modelling assumptions and limitations

- No further updates have been made to the 2016 model, other than those detailed in Section 2.
- The hydraulic modelling does not represent flooding from; surface water, groundwater or sewers.

4 Conclusions and recommendations

- JBA Consulting were commissioned by P & C James to undertake hydraulic modelling to inform an FCA for a proposed development site at Swansea Valley Business Park, Ystalyfera.
- The Ysgol Gyfun Ystalyfera FCA model, developed in 2016 by JBA Consulting was updated as part of this study. The 1D structure model representation and inflow hydrology was updated to comply with the latest methods and guidance.
- The updated model was simulated using the latest software version to generate flood risk mapping for the 1% AEP event with an allowance for climate change and the 0.1% AEP events.
- Results from the updated modelling show that the proposed development floods in neither the 1% AEP plus climate change event nor the 0.1% AEP event.

5 Bibliography

Welsh Assembly Government. (2004). *Technical Advice Note 15: Development and Flood Risk.*

Welsh Government. (2016). *Flood Consequence Assessments: Climate change allowances.*

Appendix A: FEH calculation record

Flood estimation report: Afon Twrch & Afon Tawe, Swansea

Introduction

This report template is based on a supporting document to the Environment Agency's flood estimation guidelines. It provides a record of the hydrological context, the method statement, the calculations and decisions made during flood estimation and the results.

Contents

Approval

	Name and qualifications	Date
Method statement prepared by:	Kate Drewett BSc MSc	02/08/2019
Method statement reviewed by:	Jenni Essex BSc MSc PhD CEnv MCIWEM C.WEM	12/08/2019
Calculations prepared by:	Kate Drewett BSc MSc	02/08/2019
Calculations reviewed by:	Jenni Essex BSc MSc PhD CEnv MCIWEM C.WEM	12/08/2019

Revision History

Revision reference	Date issued	Amendments	Issued to
V1.0	14/08/2019	-	CB3 Consult Ltd

Abbreviations

AEP .....Annual Exceedance Probability

AM.....Annual Maximum

AREA .....Catchment area (km^2)

BFI .....Base Flow Index

BFIHOST .....Base Flow Index derived using the HOST soil classification

CFMP .....Catchment Flood Management Plan

CPRE .....Council for the Protection of Rural England

FARL.....FEH index of flood attenuation due to reservoirs and lakes

FEH .....Flood Estimation Handbook

FSR .....Flood Studies Report

HOST.....Hydrology of Soil Types

NRA.....Natural Resources Wales

NRFA .....National River Flow Archive

OS.....Ordnance Survey

POT .....Peaks Over a Threshold

QMED .....Median Annual Flood (with return period 2 years)

ReFH.....Revitalised Flood Hydrograph method

SAAR .....Standard Average Annual Rainfall (mm)

SPR .....Standard percentage runoff

SPRHOST .....Standard percentage runoff derived using the HOST soil classification

Tp(0) .....Time to peak of the instantaneous unit hydrograph

URBAN .....Flood Studies Report index of fractional urban extent

URBEXT1990 .....FEH index of fractional urban extent

URBEXT2000 .....Revised index of urban extent, measured differently from URBEXT1990

WINFAP-FEH.....Windows Frequency Analysis Package – used for FEH statistical method

1 Method statement

1.1 Requirements for flood estimates

Overview	The purpose of the study is to update an existing 1D-2D model of the Afon Tawe and Afon Twrch at Ystalyfera, South Wales, determine the flood risk for a development site at Swansea Valley Business Park (approximate NGR 276499, 208214). This requires a new hydrological assessment for the location of interest to ensure that the most appropriate flood flow estimates are used in the model, using the latest methods, data and software. Design peak flow estimates and hydrographs are required for the purposes of the hydraulic modelling and will be generated for a range of annual exceedance probability (AEP) events. However, for the purposes of this study, only the 1% and 0.1% AEP events are required to be modelled. The effects of climate change will be accounted for using the latest guidance[1]. An uplift of 30% will be made to the 1% AEP flow estimates, based on the location of the catchment within the Western Wales district.
Project scope	The study is being undertaken for a small development application; the project scope reflects this purpose. There is a limited amount of time available for the hydrological assessment, which constrains the complexity to a routine assessment: • Brief Internet search only for information on historical flooding. • No rating reviews or flood event analysis for local gauges. • No consideration of fluvial-fluvial joint probability of flooding from the Afon Tawe and Afon Twrch. • Previous hydrological analysis will be assessed to identify if this can be made use of within the current study.

[1] Welsh Government (2016) CL-03-16 Guidance for Flood Consequence Assessments – Climate Change Allowances. Available at: https://gweddill.gov.wales/docs/desh/publications/160831guidance-for-flood-consequence-assessments-climate-change-allowances-en.pdf

1.2 The catchment

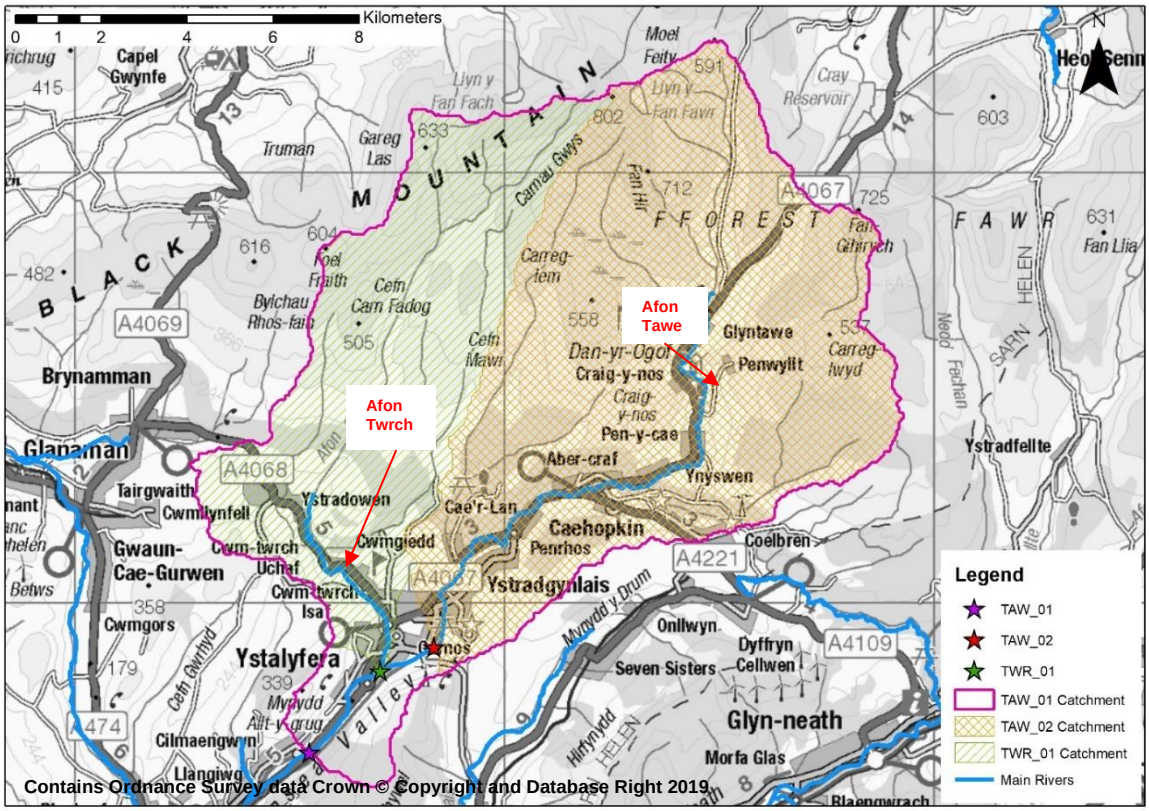


Figure 1-1 Catchment overview & location of flow estimation points

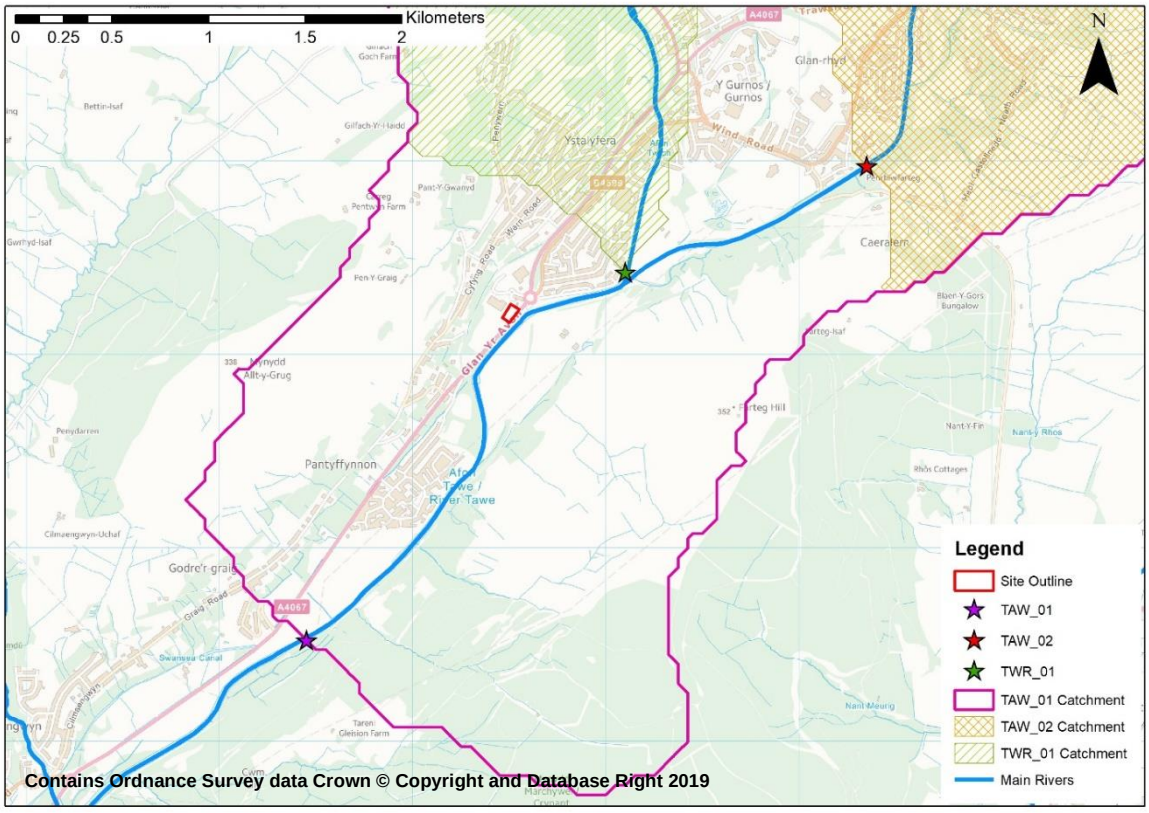


Figure 1-2 Site location

Description	The Afon Tawe rises in the Brecon Beacons near Moel Feity. It flows in a south-westerly direction to Swansea, where it discharges into the Bristol Channel. The topography is steep throughout the catchment. The main tributaries are the River Twrch which joins the Tawe at Ystalyfera, the Cwm Du at Ynsmeudwy, the Upper Clydach River at Pontardawe and Cwm Clydach joins the Tawe downstream at Clydach. The Afon Tawe has a catchment area of approximately 924m^2 just upstream of the confluence with the Twrch. The Afon Twrch rises in the Black Mountains near Llyn y Fan Fach and flows in a southerly direction to the Afon Tawe at Ystalyfera. The main tributaries are the Nant Gyws and the Afon Llynfell. The Afon Twrch catchment is approximately 50km^2 at the confluence with the Tawe. Both catchments are essentially rural with most urbanisation concentrated in the lower catchment and along the watercourses. The main settlements within the Twrch catchment are Cwmllynfell, Cwm-twrch Uchaf, Cwm-twrch Isaf and Gurnos before the Twrch joins the Tawe at Ystalyfera. There are former opencast mine workings in the lower catchment and some forested areas. The British Geological Survey website[2] 1:50,000 scale mapping shows the catchment to be underlain by the following: • Upper catchment: ○ Upper and Lower Devonian Rocks (undifferentiated) – sandstone and conglomerate, interbedded ○ Dinantian Rocks (undifferentiated) – limestone with subordinate sandstone and argillaceous rocks, with some superficial deposits of till ○ Millstone Grit Group – mudstone, siltstone and sandstone, with some superficial deposits of till • Lower catchment: ○ Pennine and South Wales Lower and Middle Coal Measures Formations – mudstone, siltstone, sandstone, coal, ironstone and ferricrete, with some superficial deposits of till ○ South Wales Upper Coal Measures Formation – mudstone, siltstone, sandstone, coal, ironstone and ferricrete. Soils in the upper catchment are mostly described as slowly permeable, wet, very acid upland soils. Downstream of Ystradgynlais, soils are more mixed including some areas of freely draining acid loamy soils[3]. The catchment response to rainfall is likely to be rapid due to the steep topography and reasonably impermeable geology and soils. The historical mining operations may have changed the natural runoff response of the catchment. It is difficult to determine the exact consequences of this, certainly not without a detailed investigation of available data; this assessment is not within the scope of the study.

1.3 Source of flood peak data

Source	NRFA peak flows dataset, Version 7, released October 2018. This contains data up to water year 2016-17.

[2] http://mapapps.bgs.ac.uk/geologyofbritain/home.html
[3] http://landis.org.uk/sooilscapes/index.cfm

1.4 Gauging stations (flow or level)

Water-course	Station name	NRFA number	Catchment area (km²)	Type (rated / ultrasonic / level…)	Start of record and end if station closed
Twrch	Gurnos	Unknown	49.9	Level	N/A

1.5 Other data available and how it has been obtained

Type of data	Data relevant to this study?	Data available ?	Source of data	Details
Check flow gaugings	No	N/A	N/A	N/A
Historic flood data	Yes	Yes	Various	An internet search found reports of landslips and surface water flooding in 2012 and 2016. A flood investigation report[4] revealed surface water and river flooding on 3rd September 2016 caused internal flooding to a number of properties on Gough Road in Ystalyfera.
Flow or river level data for events	No	N/A	N/A	N/A
Rainfall data for events	No	N/A	N/A	N/A
Potential evaporation data	No	N/A	N/A	N/A
Results from previous studies	Yes	Yes	JBA Consulting	JBA Consulting. April 2013. Cwm Twrch 1D-2D Flood Hazard Modelling. JBA Consulting. November 2016. Ysgol Gyfun Ystalyfera FCA.
Other data or information	No	N/A	N/A	N/A

1.6 Hydrological understanding of catchment

Conceptual model	The main site of interest is the proposed development site on the right bank of the River Tawe, downstream of the confluence of the Twrch and Tawe. Peak flows in the Afon Twrch and Tawe exceeding the channel capacity is the most likely cause of flooding to the site. There is a road bridge and footbridge across the Afon Tawe adjacent to the site; these do not

[4] Neath Port Talbot Council, 2017. Investigation Report into Flooding Incident of 3rd September 2016 Gough Road, Ystalyfera.

	appear to be a significant constriction to flow.
Unusual catchment features	There are former opencast mine workings within the catchments. It is not known how these will affect runoff response from the catchment and they have not been specifically considered within this assessment (not within scope).

1.7 Initial choice of approach

Is FEH appropriate?	Yes
Initial choice of method(s) and reasons How will hydrograph shapes be derived if needed? Will the catchment be split into sub-catchments? If so, how?	Both FEH Statistical and ReFH2 methods are suitable for flood flow estimation for the Afon Twrch and Tawe catchments. The catchments are not large, permeable or urbanised. The FEH Statistical and ReFH2 methods will both be applied, and the results compared as there no clear reason to prefer one method over the other at this stage. Hydrograph shapes will be derived using the ReFH2 model. If the FEH Statistical method generates the preferred design peak flow estimates, the ReFH2 hydrographs will be fitted to the Statistical peaks. Intervening area catchment descriptors will be derived for the area between lumped catchment flow estimation points. Lateral inflows will be applied to the model across this reach, if required.
Software to be used (with version numbers)	FEH Web Service[5]/ WINFAP v3.0.003[6] / ReFH2.2

[5] CEH 2015. The Flood Estimation Handbook (FEH) Online Service, Centre for Ecology & Hydrology, Wallingford, Oxon, UK.

[6] WINFAP-FEH v3 © Wallingford HydroSolutions Limited and NERC (CEH) 2009.

2 Locations where flood estimates required

The table below lists the locations of subject sites. The site codes listed below are used in all subsequent tables to save space.

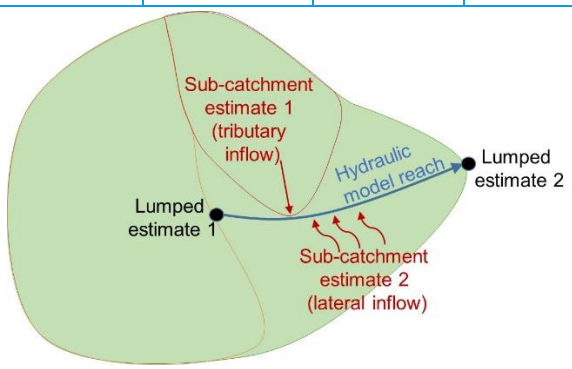
2.1 Summary of subject sites

Site code	Type of estimate L: lumped catchment S: Sub-catchment	Watercourse	Name or description of site	Easting	Northing	AREA on FEH CD-ROM (km^2)	Revised AREA if altered
TWR_01	L	Afon Twrch	Afon Twrch catchment at confluence with Afon Tawe	277100	208450	50.7	-
TAW_01	L	Afon Tawe	Afon Tawe at Godre'r-graig (downstream model extent)	275450	206550	150.6	-
TAW_02	L	Afon Tawe	Afon Tawe upstream of Glan-rhyd Bridge (upstream model extent)	278350	209000	91.8	-
TAW_01_IA	S	Afon Tawe	Intervening area between TAW_02, TWR_01 and TAW_01	-	-	-	8.1

Note: Lumped catchments (L) are complete catchments draining to points at which design flows are required.

Sub-catchments (S) are catchments or intervening areas that are being used as inputs to a semi-distributed model of the river system. There is no need to report any design flows for sub-catchments, as they are not relevant: the relevant result is the hydrograph that the sub-catchment is expected to contribute to a design flood event at a point further downstream in the river system. This will be recorded within the hydraulic model output files. However, catchment descriptors and ReFH model parameters should be recorded for sub-catchments so that the results can be reproduced.

The schematic diagram illustrates the distinction between lumped and sub-catchment estimates.



2.2 Important catchment descriptors at each subject site (incorporating any changes made)

Red text indicates changes made to FEH catchment descriptors. $URBEXT_{2000}$ has been updated to the current year (2019).

Site code	FARL	PROPWET	BFIHOST	DPLBAR (km)	DPSBAR (m/km)	SAAR (mm)	URBEXT 2000[7]	FPEXT
TWR_01	0.995	0.62	0.377	10.14	124.1	1987	0.016	0.035
TAW_01	0.994	0.62	0.373	14.84	141.6	2024	0.018	0.042
TAW_02	0.993	0.62	0.358	12.59	146.8	2071	0.014	0.039
TAW_01_IA	-	0.62	0.518	3.15	192.1	1724	0.076	-

2.3 Checking catchment descriptors

Record how catchment boundary was checked and describe any changes	The catchment boundaries exported from the FEH Web Service were compared to Ordnance Survey (OS) contour mapping[8], spot heights[9] and 2m LiDAR data. The catchment boundaries from the FEH Web Service appear reasonable and correlate with the mapping for the upstream catchment to the study site. Some minor discrepancies were found between the FEH catchment boundaries and the contours, spot heights and watercourse lines. One noted difference was with the TWR_01 catchment boundary in the south-western corner. It was decided to retain the FEH catchment area which is the larger value and will therefore be more conservative, as done in the 2016 study.
Record how other catchment descriptors were checked and describe any changes.	A qualitative check of the FEH Web Service BFIHOST values was undertaken by comparing it to the geology and soils detailed in Section **Error! Reference source not found.**. The BFIHOST value is consistent with the geology and soils shown to underlie the catchments. The FARL values for all flow estimation points are supported by OS mapping which shows only small online ponds on the rivers. A qualitative check of the $URBEXT_{2000}$ values were made by comparing the FEH Web service values to current OS mapping. The value is as would be expected for an essentially rural catchment with a small amount of urbanisation in the lower extent. No changes were made except to update $URBEXT_{2000}$ to the current year (2019).
Source of URBEXT	URBEXT2000
Method for updating of URBEXT	CPRE formula from 2006 CEH report on URBEXT2000

[7] URBEXT 2000 updated to 2019
[8] OS Open Data. Terrain50_Contours
[9] OS Open Data. Terrain50_SpotHeights

3 Statistical method

3.1 Overview of estimation of QMED at each subject site

Site code	Initial QMED rural (m^3/s) (from catchment descriptors)	Final method	Data transfer					Urban adjust-ment factor (UAF)	Final QMED estimate (m^3/s)
			NRFA numbers for donor sites used (see 3.3)	Distance between centroids d_{ij} (km)	Moderated QMED adjustment factor, (A/B)[a]	If more than one donor			
						Weight	Weighted ave. adjustment		
TWR_01	58	DT	58008 59001	9.54 3.45	1.07 1.18	0.5 0.5	1.12	1.116	65.7
TAW_01	150	DT	58008 59001	8.76 4.61	1.08 1.16	0.5 0.5	1.11	1.108	168.9
TAW_02	104	DT	58008 59001	9.72 6.85	1.07 1.14	0.5 0.5	1.10	1.098	115.2

Are the values of QMED spatially consistent?	Yes, TAW_01 is the most downstream and has the greatest QMED. The sum of the upstream flows is greater than the downstream flow, which is as would be expected.
Method used for urban adjustment for subject and donor sites	WINFAP v4[10]

Parameters used for WINFAP v4 urban adjustment if applicable		
Impervious fraction for built-up areas, IF	Percentage runoff for impervious surfaces, PR_{imp}	Method for calculating fractional urban cover, URBAN
0.3	70%	From updated URBEXT2000

Notes

Methods: AM – Annual maxima; POT – Peaks over threshold; DT – Data transfer (with urban adjustment); CD – Catchment descriptors alone (with urban adjustment); BCW – Catchment descriptors and bankfull channel width (add details); LF – Low flow statistics (add details).

The QMED adjustment factor A/B for each donor site is given in Table 3.2. This is moderated using the power term, a, which is a function of the distance between the centroids of the subject catchment and the donor catchment. The final estimate of QMED is: $(A/B)^a \times QMED_{initial} \times UAF$

Important note on urban adjustment

The method used to adjust QMED for urbanisation published in Kjeldsen (2010)[11] in which PRUAF is calculated from BFIHOST is not correctly applied in WINFAP-FEH v3.0.003. Significant differences occur only on urban catchments that are highly permeable.

[10] Wallingford HydroSolutions (2016). WINFAP 4 Urban adjustment procedures.

[11] Kjeldsen, T. R. (2010). Modelling the impact of urbanization on flood frequency relationships in the UK. Hydrol. Res. **41**. 391-405.

3.2 Search for donor sites for QMED (if applicable)

Comment on potential donor sites	Hydrology estimations were carried out in 2016 by JBA for the Afon Twrch. The two donor sites used in the 2016 study have been retained for the current study. Potential donor sites were investigated using the function within WINFAP coupled with the National River Flow Archive (NRFA) website to search for nearby gauges. Their catchment descriptor derived QMED value was compared with their observed QMED value to determine the magnitude of the adjustment factor. Six stations were considered in detail as donors for the TAW_01 and TAW_02 catchments: • 58002 – Neath at Resolven • 58006 – Mellte at Pontneddfechan • 58008 – Dulais at Cilfrew • 59001 – Tawe at Ynystanglws • 59002 – Loughor at Tir-y-dail • 60009 – Sawdde at Felin-y-cwm 60009 and 59002 were rejected as the SAAR value was significantly lower than the study catchments and they had the highest QMED adjustment factors. 59001 is on the Afon Tawe but located several kilometres downstream of the study site; catchment centroids for the study catchments are the closest to this gauge. It also has similar FARL (0.996) and BFIHOST (0.407) values, however the SAAR value (1890mm) is lower than the study catchments. 58008 has similar FARL (0.999), BFIHOST (0.377) and URBEXT (0.0181) values, but also has a lower SAAR value (1806mm) than the study catchments. 58002 and 58006 have the most similar SAAR values to the study catchments, however they have lower FARL values (0.983 and 0.975 respectively), indicating a greater attenuation to lakes and reservoirs. 58008 and 58006 have the lowest QMED adjustment factors. 58008 and 59001 are the two closest gauges to TAW_01. 58002 and 59001 are the two closest gauges to TAW_02. It was decided than an equal weighting of 59001 and 58008 was most appropriate for both TAW_01 and TAW_02 catchments to adjust QMED. This is consistent with the approach used for TWR_01.

3.3 Donor sites chosen and QMED adjustment factors

NRFA no.	Reasons for choosing	Method (AM or POT)	Adjust-ment for climatic variation ?	QMED from flow data (A)	QMED from catchment descriptor s (B)	Adjust -ment ratio (A/B)
58008	See Section 3.2	AM	No	56.5	46.9	1.20
59001	See Section 3.2	AM	No	253	185	1.37

3.4 Derivation of pooling groups

In order to avoid discontinuities in flow estimates along watercourses it is useful to use as few pooling groups as possible and to identify if one pooling group can be used to represent several flow estimation points. Default pooling groups were generated for the three locations

and compared. All three pooling groups had quite different station composition and it was decided to use a separate pooling group for each location in this case.

Name of group	Site code from whose descriptors group was derived	Subject site treated as gauged?	Changes made to default pooling group, with reasons	Weighted average L-moments
TWR_01	TWR_01	No	No changes made	L-CV = 0.187 L-Skew = 0.196
TAW_01	TAW_01	No	No changes made	L-CV = 0.169 L-Skew = 0.174
TAW_02	TAW_02	No	No changes made	L-CV = 0.172 L-Skew = 0.168
Note: Pooling groups were derived using the procedures from Science Report SC050050 (2008).				

3.5 Derivation of flood growth curves at subject sites

Site code	Method	If P, ESS or J, name of pooling group (Error! Reference source not found.)	Distribution used and reason for choice	Note any urban adjustment or permeable adjustment	Parameters of distribution	Growth factor for 100-year return period
TWR_01	P	TWR_01	GL – distribution that provides best fit.	v3 urban adjustment applied Permeable adjustment not applied as most sites in the pooling group have SPRHOST >20%	Location: 1.000 Scale: 0.184 Shape: -0.199	2.38
TAW_01	P	TAW_01	GL – distribution that provides best fit.		Location: 1.000 Scale: 0.167 Shape: -0.177	2.18
TAW_02	P	TAW_02	GL – distribution that provides best fit.		Location: 1.000 Scale: 0.171 Shape: -0.170	2.19
Notes Methods: SS – Single site; P – Pooled; ESS – Enhanced single site; J – Joint analysis A pooling group (or ESS analysis) derived at one gauge can be applied to estimate growth curves at a number of ungauged sites. Each site may have a different urban adjustment, and therefore different growth curve parameters. Urban adjustments are all carried out using the method of Kjeldsen (2010). Growth curves were derived using the procedures from Science Report SC050050 (2008).						

3.6 Flood estimates from the statistical method

Site code	Flood peak (m^3/s) for the following AEP (%) events										
	50	**20**	**10**	**5**	**3.33**	**2**	**1.33**	**1**	**0.5**	**0.2**	**0.1**
TWR_01	66	85	99	114	124	137	148	157	179	214	245
TAW_01	169	213	245	278	299	327	351	369	416	488	550
TAW_02	115	146	168	190	205	224	240	252	284	332	374

4 Revitalised flood hydrograph 2 (ReFH2) method

4.1 Catchment sub-divisions for ReFH2 model

Site code	Area (km^2)			
	Rural or un-developed	Paved	Only relevant if significant transfers of water via sewers crossing catchment boundaries…	
			Paved with sewers draining out of topographic catchment	Paved outside topographic catchment with sewers draining into catchment
TWR_01	49.44	1.27	N/A	N/A
TAW_01	146.38	4.25	N/A	N/A
TAW_02	89.79	2.01	N/A	N/A
Sources of information for creating sub-divisions	N/A		**Sewer capacity** (return period / rainfall intensity / flow rate) and source of information	N/A

4.2 Parameters for ReFH2 model

Site code	Method	Tp_{rural} (hours)	Tp_{urban} (hours)	C_{max} (mm)	PR_{imp} % runoff for impermeable surfaces	BL (hours)	BR
TWR_01	CD	2.70	1.35	261.46	70	35.45	1.12
TAW_01	CD	3.21	1.61	258.75	70	38.28	1.11
TAW_02	CD	2.89	1.45	248.87	70	36.02	1.06
Brief description of any flood event analysis carried out					N/A		
Methods: OPT: Optimisation, BR: Baseflow recession fitting, CD: Catchment descriptors, DT: Data transfer (give details)							

4.3 Design events for ReFH2 method

Site code	Season of design event	Storm duration (hours)	Storm area for ARF (if not catchment area)	Source of design rainfall statistics (FEH99 or FEH13)
TWR_01	Winter	8.5	-	FEH13
TAW_01	Winter	9.5	-	FEH13
TAW_02	Winter	8.5	-	FEH13
Are the storm durations likely to be changed in the next stage of the study, e.g. by optimisation within a hydraulic model?			Yes, all inflow hydrographs will use a 9.5 hour storm duration and an areal reduction factor based on the TAW_01 location. This is the flow estimation point closest to the site of interest (development site).	

4.4 Flood estimates from the ReFH2 method

Site code	Flood peak (m^3/s) for the following AEP (%) events										
	50	**20**	**10**	**5**	**3.33**	**2**	**1.33**	**1**	**0.5**	**0.2**	**0.1**
TWR_01	58	74	85	96	103	112	120	125	142	170	199
TAW_01	160	204	235	265	284	309	330	346	389	465	541
TAW_02	111	143	165	187	201	219	234	245	276	329	382

5 Discussion and summary of results

5.1 Comparison of results from different methods

This table compares peak flows from various methods with those from the FEH Statistical method at example sites for two key return periods. Blank cells indicate that results for a particular site were not calculated using that method.

Site code	Ratio of peak flow to FEH Statistical peak	
	50% AEP	1% AEP
	ReFH2/FEH	ReFH2/FEH
TWR_01	0.89	0.80
TAW_01	0.95	0.94
TAW_02	0.97	0.97

5.2 Final choice of method

Choice of method and reasons	The comparison of 50% and 1% AEP flows in Section 5.1 shows that the ReFH2 peak flow estimates are lower than the FEH Statistical flows. The difference is larger for the Afon Twrch, with the 1% AEP event estimate from ReFH2 method being 20% lower than that from the FEH Statistical method. For the Afon Tawe the difference is only 3%-6%. FEH Statistical is the preferred method for generating the design peak flow estimates for the study catchment as QMED has been improved using local donors. ReFH2 is based on catchment descriptors only. It is recommended that the FEH Statistical method peak flow estimates are taken forward but with the ratio from ReFH2 applied to events above 1% AEP, as recommended in NRW guidance[12].
How will the flows be applied to a hydraulic model?	TWR_01 will be input as a point inflow to the top of the Afon Twrch watercourse model extent in the hydraulic model. TAW_02 will be input as a point inflow to the top of the Afon Tawe watercourse model extent in the hydraulic model. TAW_01A will be distributed along the Afon Tawe, between TAW_02 and TAW_01. Modelled flows will be checked against the target flows at TAW_01 and adjustments made to the intervening area hydrographs, if required.

5.3 Assumptions, limitations and uncertainty

List the main assumptions made (specific to this study)	The main assumptions are: • The FEH Web Service catchment boundary definition is reasonable, although there are some inaccuracies when compared to contour data and watercourse lines. • Stations 58008 and 59001 are the most representative local donors with similar catchment descriptors and characteristics to the three study catchments and hence a similar flood response. • The pooling groups used to define the growth curve for the FEH Statistical method is representative of the catchments. • The ReFH2 model generates a representative hydrograph shape for the watercourses.

[12] Natural Resources Wales. December 2017. GN008. Flood estimation: technical guidance.

Discuss any particular limitations	The main limitations are: • There is no reported flood history for the development site against which the design peak flow estimates can be verified. • There is no flow gauge on the Afon Twrch which can be used as a donor.
Give what information you can on uncertainty in the results,	A UK average measure of uncertainty for the FEH Statistical method is presented in a technical report[13] generated by a R&D project into FEH, local data and uncertainty (Environment Agency funded consortium of JBA, CEH and others). The 95% confidence limits for a 1% AEP flood estimate for a rural catchment ($URBEXT_{2000}$ < 0.03) are 0.47-2.12 times the best estimate with a donor adjustment of QMED (one donor). Note: Confidence limits are provided for no donor, one donor and six donors; values are not provided for two donors. It is not possible to directly quantify the uncertainty for the ReFH2 method.
Comment on the suitability of the results for future studies,	The design peak flow estimates and hydrographs were derived for the purposes of this modelling study. If peak flow estimates and hydrographs are required for a different purpose it is recommended that, at minimum, a review of the results is carried out.

5.4 Checks

Are the results consistent, for example at confluences?	Yes, flow estimates increase downstream. The sum of flows at TWR_01 and TAW_02 are larger than the flow at TAW_01, as would be expected (peak flows from the Twrch and Tawe are unlikely to coincide).
What do the results imply regarding the return periods of floods during the period of record?	There are no gauges within the study area to compare flow estimates to.
What is the range of 100-year growth factors? Is this realistic?	The 1% AEP growth factor for the methods is: • FEH Statistical: 2.18 - 2.38 • ReFH2: 2.15 - 2.20 The typical range is 2.1-4.0 therefore both methods are at the lower extent of, but within, the range. This is consistent with the 2016 study.
If 1000-year flows have been derived, what is the range of ratios for 1000-year flow over 100-year flow?	The 0.1% / 1% AEP event ratio for the methods is: • FEH Statistical: 1.48 - 1.57 • ReFH2: 1.56 – 1.59
How do the results compare with those of other studies? Explain any differences and conclude which results should be preferred.	JBA Consulting undertook flood modelling studies in 2013 and 2016, one of the flow estimation points is at the same location as used for this study (TWR_01) – the Afon Twrch just upstream of the confluence with the Afon Tawe. The flow estimates for all three studies can therefore be directly compared. The estimates for the 50%, 1% and 0.1% AEP events are provided in the table below. **Study** | **Flow (m^3/s) for the following AEP (%) events**

[13] Environment Agency, 2017. Using local data to reduce uncertainty in flood frequency estimation.

	50	**1**	**0.1**
2013	66	152	297
2016	68	146	231
2019	68	157	249

There is limited information regarding the approach undertaken for the 2013 study. However, the main difference for the 2013 study to the 2016 and current study is that QMED was adjusted using the Gurnos gauging station and the adjustment was applied directly without the distance weighting. The Gurnos gauge was not used for this study or in 2016 as it has been level-only since 2003. Also a storm duration of 6.5hr was used for the 2013 study.

The 2019 50% AEP event flow estimate is ~2% lower than the 2016 study. The 2019 1% and 0.1% AEP event flow estimates are ~7% larger than the 2016 study.

The 2016 study FEH Statistical flow estimates are based on QMED adjusted using the same donors as this study (58008 and 59001). A storm duration of 8.5hr was also used in the 2016 study to generate ReFH2 peak flow estimates. However, a slightly different pooling group was used in the 2019 study compared to the 2016 study which may explain some differences in flow estimates.

The latest peak flow data (NRFA v7) has been used in the pooling group analysis for this 2019 study. This contains an additional two years of data (for gauging stations in England, Wales & Northern Ireland) compared to the dataset used in the 2016 study. Therefore the 2019 results should be preferred as these use the latest methods, data and guidance.

Are the results compatible with the longer-term flood history?	There is no information on reported flooding of the study site to make this assessment.
Describe any other checks on the results	Following the initial model run, the flows will be sense-checked to ensure that the flow inputs result in realistic outputs. Modelled flows at TAW_01 will be checked against target flows for this location and adjustments made to the intervening area hydrographs, if required.

5.5 Final results

These estimates have been generated using the FEH Statistical method with QMED adjusted using an equal weighting of Stations 59001 and 58008 for TWR_01, TAW_01 & TAW_02. The ReFH2 ratio has been applied to events above the 1% AEP event.

Site code	**Flood peak (m^3/s) for the following AEP (%) events**										
	50	**20**	**10**	**5**	**3.33**	**2**	**1.33**	**1**	**0.5**	**0.2**	**0.1**
TWR_01	66	85	99	114	124	137	148	157	177	212	249
TAW_01	169	213	245	278	299	327	351	369	415	495	577
TAW_02	115	146	168	190	205	224	240	252	284	338	393

If flood hydrographs are needed for the next stage of the study, where are they provided?	Hydrographs.xlsx

6 Annex

TWR_01 Pooling Group						
Station	Distance	Years of data	QMED AM	L-CV	L-SKEW	Discordancy
46007 (West Dart @ Dunnabridge)	0.188	36	70.1	0.177	0.162	0.073
58006 (Mellte @ Pontneddfechan)	0.38	46	86.9	0.170	0.097	1.755
47014 (Walkham @ Horrabridge)	0.411	44	39.6	0.221	0.235	0.679
21030 (Megget Water @ Henderland)	0.464	13	77.7	0.216	0.074	2.352
84020 (Glazert Water @ Milton of Campsie)	0.507	37	54.2	0.132	0.075	1.497
21017 (Ettrick Water @ Brockhoperig)	0.524	41	60.4	0.203	0.276	0.278
55004 (Irfon @ Abernant)	0.534	45	56.5	0.159	0.255	1.560
73009 (Sprint @ Sprint Mill)	0.607	48	42.1	0.180	0.199	0.044
73017 (Kent @ Bowston)	0.624	18	63.2	0.226	0.403	1.206
73011 (Mint @ Mint Bridge)	0.625	48	54.8	0.215	0.303	0.394
76014 (Eden @ Kirkby Stephen)	0.673	46	86.8	0.170	-0.026	1.488
48001 (Fowey @ Trekeivesteps)	0.693	48	17.5	0.22	0.276	0.409
74001 (Duddon @ Duddon Hall)	0.783	50	120.913	0.152	0.244	1.265
Total		520				
Weighted means				0.187	0.196	

TAW_01 Pooling Group						
Station	Distance	Years of data	QMED AM	L-CV	L-SKEW	Discordancy
58002 (Neath @ Resolven)	0.345	39	220.0	0.149	0.233	0.733
79004 (Scar Water @ Capenoch)	0.441	43	132.9	0.087	0.070	1.998
72015 (Lune @ Lunes Bridge)	0.447	38	202.1	0.145	0.150	0.519
55026 (Wye @ Ddol Farm)	0.448	48	115.2	0.174	0.125	0.592
73012 (Kent @ Victoria Bridge)	0.505	39	141.8	0.209	0.286	0.760
56006 (Usk @ Trallong)	0.506	44	163.6	0.193	0.148	1.204
60006 (Gwili @ Glangwili)	0.507	49	78.5	0.159	0.167	0.300
75009 (Greta @ Low Briery)	0.544	45	110.9	0.234	0.273	0.985
4005 (Meig @ Glenmeanie)	0.569	21	111.3	0.179	0.244	1.093
16003 (Ruchill Water @ Cultybraggan)	0.581	45	148.1	0.145	0.058	1.157
59001 (Tawe @ Ynystanglws)	0.598	43	253.1	0.123	0.248	1.554
81003 (Luce @ Airyhemming)	0.630	40	164.2	0.166	0.091	0.551
76004 (Lowther @ Eamont Bridge)	0.638	55	110.385	0.244	0.19	1.554
Total		549				
Weighted means				0.169	0.174	

TAW_02 Pooling Group						
Station	Distance	Years of data	QMED AM	L-CV	L-SKEW	Discordancy
74001 (Duddon @ Duddon Hall)	0.223	50	120.9	0.152	0.244	1.063
16003 (Ruchill Water @ Cultybraggan)	0.232	45	148.1	0.145	0.058	0.461
58012 (Afan @ Marcroft Weir)	0.254	37	94.9	0.159	0.093	1.264
55004 (Irfon @ Abernant)	0.41	45	56.5	0.159	0.255	0.900
47024 (Tavy @ Tavistock Abbey Bridge)	0.43	23	81.8	0.206	0.139	1.390
58006 (Mellte @ Pontneddfechan)	0.508	46	86.9	0.170	0.097	1.366
96004 (Strathmore @ Allnabad)	0.514	19	198.5	0.183	0.234	0.474
73017 (Kent @ Bowston)	0.54	18	63.2	0.226	0.403	1.943
46008 (Avon @ Loddiswell)	0.585	37	63.1	0.171	0.069	1.708
4005 (Meig @ Glenmeanie)	0.636	21	111.3	0.179	0.244	0.202
60006 (Gwili @ Glangwili)	0.708	49	78.5	0.159	0.167	0.148
47020 (Inny @ Bealsmill)	0.727	33	35.0	0.198	0.135	0.998
73011 (Mint @ Mint Bridge)	0.728	48	54.835	0.215	0.303	0.734
78004 (Kinnel Water @ Redhall)	0.747	40	78.224	0.118	0.011	1.35
Total		511				
Weighted means				0.172	0.168	

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